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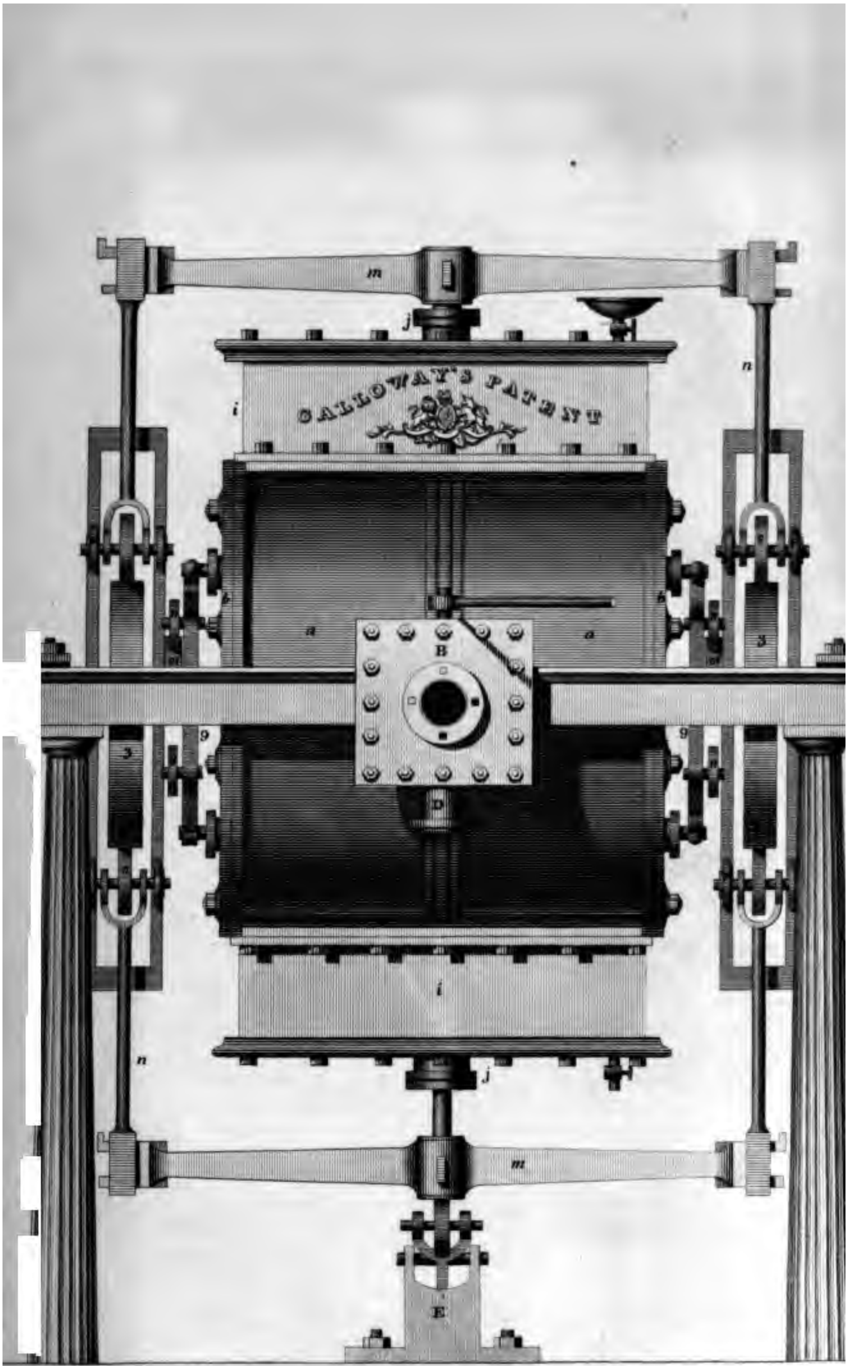

Drawn by E. Galloway *Engrav'd by J. Knox*

HISTORY

OF THE

Steam Engine,

FROM ITS FIRST INVENTION TO THE PRESENT TIME.

ILLUSTRATED

By numerous Engravings from Original Drawings,

MADE EXPRESSLY FOR THIS WORK,

BY ELIJAH GALLOWAY,

ENGINEER.

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TO THE

MECHANICS OF GREAT BRITAIN,

WHOSE INTELLIGENCE, INGENUITY AND INDUSTRY,

CONSTITUTE THE WEALTH AND GLORY OF THE PEOPLE,

BY WHOSE TALENT IN CONTRIVANCE AND EXECUTION

IN MACHINERY OF EVERY DESCRIPTION,

This Island

HAS BEEN ENABLED TO SURPASS ALL OTHERS IN THE EXCELLENCE OF HER MANUFACTURE:

AND WHO, IN PARTICULAR, HAVE BEEN CHIEFLY INSTRUMENTAL

IN BRINGING

The Steam Engine

TO ITS PRESENT STATE OF IMPROVEMENT,

THIS HISTORY OF ITS INVENTION AND PROGRESS

IS DEDICATED

BY THE AUTHOR.

PREFACE.

TWO works are at present before the public under the same title as I have chosen for my little volume, both of which have been extensively circulated, and are in the hands of most individuals to whom such works are useful or interesting. But it has been a matter of regret, that neither possess those qualifications which it might be expected would be found under such a title. It is, however, to be said, that the writers were almost the first on whom the task of research and arrangement had devolved, and that, out of the crude and undigested materials, it was somewhat difficult to form any regular well-constructed detail.

But admitting the difficulty, I am sorry to say that Partington's History of the Steam Engine has scarcely one excellence which can be praised, excepting its most elegantly finished engravings. The work itself possesses little or no originality; and such parts of it as are interesting, are

borrowed from other sources, and I grieve when I add, in many instances, copied verbatim therefrom, without the most obscure hint that they are any thing but original.

Stuart's History of Steam Engines is of a much higher character. The work throughout is, evidently, the result of long and persevering industry, and has been the means of making the public masters of much useful knowledge which had been previously beyond their reach. This qualification alone entitles the author to our warmest thanks; and there is no doubt that its utility has been estimated by the thousands of persons to whom his channels of information were inaccessible.

But even in this there are many prominent defects, most of which may be attributed, as I have said, to the difficulties under which he laboured. Many of the diagrams have scarcely any resemblance to the machines they are intended to represent; and the author, following too closely a maxim of his—" that a line of engraving is worth pages of letter-press," has left the reader to discover the principle of many of the machines, by little else than the engraving itself. Some of the most important inventions of Watt are passed over in a most careless way; as, for instance, his sun and planet wheels, and parallel motion, neither of which are so explained as to instruct any one further than they have been previously informed elsewhere: the author being contented, in place of these investigations,

to extract from other works a biographical sketch of this great man's life, and conclude it by the eloquent and impressive eulogium on his character, by Francis Jeffreys: interesting and excellent I grant, but not of such importance as to take the place of descriptions of steam machinery, in a work avowedly a history of such inventions, and not of the inventors.

The plan I propose to adopt, to avoid these defects, is, to confine myself entirely to the detail of such discoveries as have been useful, or such as, not being useful in themselves, yet have contributed to our advancement in knowledge and experience on this important subject. I shall endeavour to expunge or slightly notice those which have been old ideas re-modified, or which have existed no where but in the brain of the unpracticed projector.

One thing I will do, which I am sure must prove satisfactory and beneficial, that is—by research among enrolled specifications of patents, lay before the public a mass of knowledge of which they are not possessed. In this part of the work no expense has been spared, and I trust that this addition to the history will prove highly entertaining and useful.

The description of my own invention will be found in its proper place. This engine, though of course in my opinion the best, should not, in the History of the Steam

Engine, occupy any other situation than that to which its date entitles it. I there give the ground of its superiority and such an enlarged detail as to make it fully understood; and, if it be possible for an inventor to give an unprejudiced description of his own discoveries, I endeavour, as a faithful historian, candidly to examine its merits,

46, London Road,
23rd May, 1826.

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CONTENTS.

HISTORY

OF THE

STEAM ENGINE.

CHAPTER I.

CONTENTS.—THE PROPERTIES OF STEAM DISCOVERED BY ACCIDENT.—HERO, THE ELDER.—DE CAUS' ENGINE.—BRANCA.—MARQUIS OF WORCESTER.—DR. PAPIN'S EXPERIMENTS.—INVENTION OF THE SAFETY VALVE.—SAVERY'S ENGINE; PAPIN'S IMPROVEMENT.—NEWCOMEN'S EXPERIMENTS.—HUMPHREY POTTER.—BEIGHTON'S IMPROVEMENTS.

THE early history of the Steam Engine is involved in great obscurity. Notwithstanding many able disquisitions in the endeavour to discover to whom the merit of first inventor is due, nothing satisfactory has been developed in the enquiry. It is singular, that until steam had arrived at some degree of perfection, as a mechanical agent, almost every one who made any slight improvements, laid claim to the rank of first discoverer. Thus different nations in Europe have set up different individuals as the persons to whom the honour should be awarded. Among such a variety of claims it is difficult to decide; we shall, therefore, content ourselves by expressing our opinion, that the elastic properties of steam have been known from the first dawn of civilization. The probability is, that the discovery was owing to the bursting of some culinary vessel, the mouth of which had been closed through ignorance of the effect which would thereby be produced. Indeed, it was impossible for mankind to have remained unacquainted with this property of vapour after hot water had been used for any purpose.

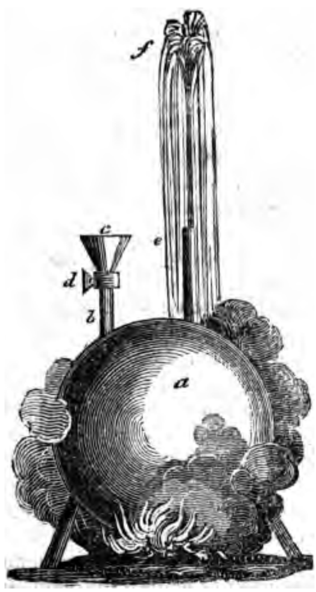
But the first individual on record who applied this known property to produce any effect, appears to have been Hero, the elder, an Alexandrian, who flourished about 130 years before the Christian era. In his work, entitled *Spiritalia,* among other ingenious discoveries, he describes a machine to which motion is to be given by the force of steam. It consisted of a hollow globe, having tubular arms running in opposite directions. These tubes had an opening at different sides near their extremity. The globe was suspended upon centres, fixed upon pillars. One of those pillars was hollow, as also was one of the centres. Steam was introduced from a cauldron, or heated vase, which, issuing through the hollow column and centre into the globe, and so through the arms into the open air, produced a rotatory

motion, in the same manner as water produces that of Barker's mill. This invention being the first in which steam was employed as an agent, entitles HERO to the honour which has been the subject of so much dispute.

In the dark ages which succeeded the overthrow of the empires of Greece and Rome, history furnishes no instance of an attempt to use the powerful agency of steam, until the year 1560, when one Mathesius suggests the practicability of a plan by which it could be employed. In Leipsig, a machine, upon a similar plan to that of Hero's, was proposed to be substituted for the turnspit-dog, then in use.

Up to this date we cannot trace any thing important relative to the application of steam, excepting what we have already stated. We are unable, at this remote period, to form any idea as to the originality of the plans which have been named. It is impossible to state whether they were descriptions of what was generally known, or they were the invention of those by whom they were claimed. Nor should our readers be surprised at the obscurity in which these matters are involved, when we reflect, that there is frequently great difficulty, even at the present day, in deciding who are the inventors of the most meritorious productions.

Having briefly stated what is recorded respecting the earlier history of the steam engine, when it had more the character of a philosophic toy than any thing truly useful, we come to speak of the first attempt towards its adoption as a powerful agent.



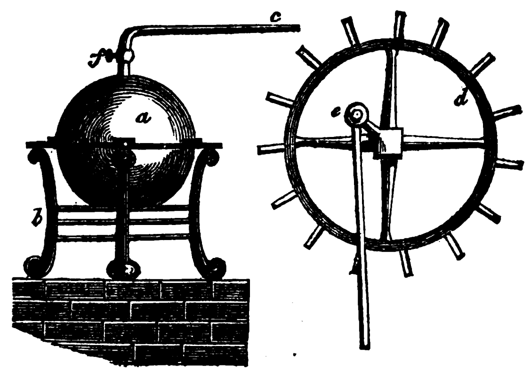
It is described in a work by Solomon de Caus, an eminent French mathematician and engineer, published in 1615, entitled "Les Raisons des Force mouvantes avec divers Desseins de Fontains."

The following description will explain the principle of his invention.

a is a spherical vessel, placed over a fire; it is furnished with two pipes, *b e*. The pipe *e* is open at the top, and reaches down to the bottom of the vessel *a*. The pipe *b* is furnished with a cock *d*, and funnel *c*. The vessel being filled with water, and fire applied, steam is speedily generated upon the surface of the water, and having no other way to escape, the cock *d* being stopped, presses on the surface, and so forces it up the tube *e* into the air, causing a jet, which varies in proportion to the elasticity of the steam within.

De Caus appears, also, to have been aware that a vacuum could be obtained by the condensation of steam, but we have no opportunity of knowing whether he ever thought of using it as a means of increasing the power of his machine.

The engine which next demands our attention, both on account of its importance and date, is that invented by Giovanni Branca, an Italian mathematician, who resided at Rome, at the commencement of the seventeenth century. We are indebted for our knowledge of this machine, to his own account, published in 1629. The drawing which he there furnishes must be understood rather as an ornamental illustration of his plan, than as the form in which it was actually constructed: we have, therefore, given one which we conceive to be more consistent with the end he proposed to effect by its use.



The boiler of this engine is represented by *a*; *b* is the fire grate; *c* a small pipe, provided with a stop cock *f*; *d* is a wheel furnished with vanes; *e* is a crank which gives motion, through the medium of the connecting rod, to a stamper for pounding drugs. The principle of action is this:—steam is generated in the boiler, and rushes violently against the vanes, which causes the wheel to revolve, and thus produces a reciprocation of the rod and stamper.

This invention had remained unnoticed but by the learned, until the last few years. It was recently described by Partington, in his

History of the Steam Engine, who goes so far as to allow Branca the merit of the *first idea*. We believe our readers will perceive that to this honour Branca has no claim. His engine is on the same principle as Hero's, only differently modified. Its ingenuity is decidedly inferior to its prototype, both in simplicity and effect.

But of all the various applications of the elastic force of steam, none have stood so high in public estimation as a brief description of "*a fire water-work*," contained in the Marquis of Worcester's celebrated "Century of Inventions," dated 1663; the original manuscript of which is preserved in the British Museum. The following is the marquis's own description:—

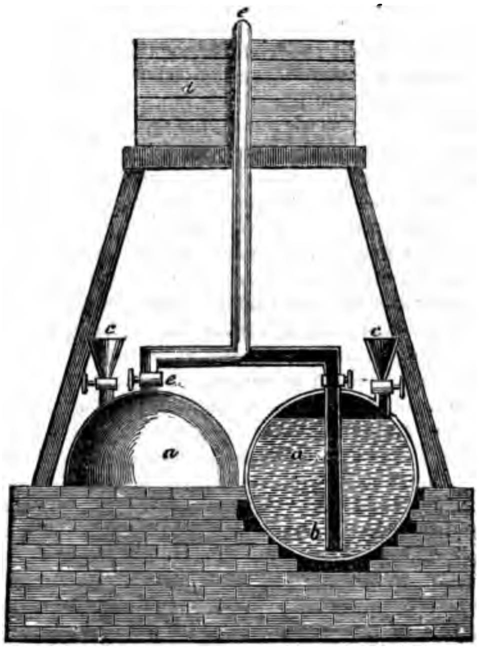
"An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards, for that must be, as the philosopher calls it, *infra sphæram activitatis*, which is but at such a distance. But this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst, and made a great crack; so that having found a way to make my vessels, so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant fountain-stream forty feet high; one vessel of water, rarified by fire, driveth up forty of cold water; and a man that tends the work, is but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water, and so successively, the fire being tended, and kept constant, which the self-same person may likewise abundantly perform in the interim, between the necessity of turning the said cocks."

From this account Dr. Robinson founds an opinion, that "the steam engine was, beyond all doubt, the invention of the Marquis of Worcester." It is probable that the learned doctor was unacquainted with De Caus' and Branca's previous experiments; or he could not have come to this conclusion. But whilst we cannot admit the marquis to be entitled to the extravagant encomiums which have been lavished upon him, we are far from disallowing his invention to possess merit and originality. The annexed drawing we consider to be a fair representation of the engine, according to the marquis's intention and description, "fulfilling the conditions of the enigma, *and no more*.

Let *a a* represent two vessels (one of them in section), *c c* two funnels, furnished with stop cocks; *b* a pipe, reaching down to the bottom; a similar pipe extends to the bottom of the other. Both these pipes are connected with a perpendicular tube *e*, which is continued above the top of the cistern or reservoir *d*. It is there bent so that the mouth shall be directed to the interior of the cistern. Let us now examine the operations of this engine.

We will suppose the vessel, of which we have given the section, to be filled with water through the funnel *c*. The cock of that funnel is then closed, as also the cock *e* of the other vessel. The fire is then lighted under the first vessel, and as soon as a sufficiency of vapour is

formed, the cock *e* of this vessel is opened. The elasticity of the steam acts upon the surface of the water, which, finding an escape through the pipe *b e*, rushes rapidly upwards into the cistern *d*. During the performance of this operation "the man that tends the work" fills the other vessel with cold water, and applies the fire to it also, so that by the time the first is exhausted, the other, upon charging the necessary cocks, "begins to force and refill," that is, *repeat the action of filling* the cistern.



By this reading of the marquis's project we have a very feasible and ingenious machine for raising water. It is evidently an improvement on De Caus' engine, and the application of another vessel constitutes this improvement. It has been the marquis's design, by the addition, to save the time which was lost between the exhaustion and re-action of a single vessel, and this he effects by the use of the two vessels.

There can be no doubt but the Marquis of Worcester was aware of the plan proposed by De Caus; we have, therefore, to regret the want of candour which made him put forth the "fire water work" as his original invention; making this deduction from his merit as a man, we feel ourselves bound to award him a greater portion of approbation than some writers have been inclined to allow him.

About the year 1680, Dr. Denys Papin, a native of Blois, commenced a series of experiments on the power of steam, which termi-

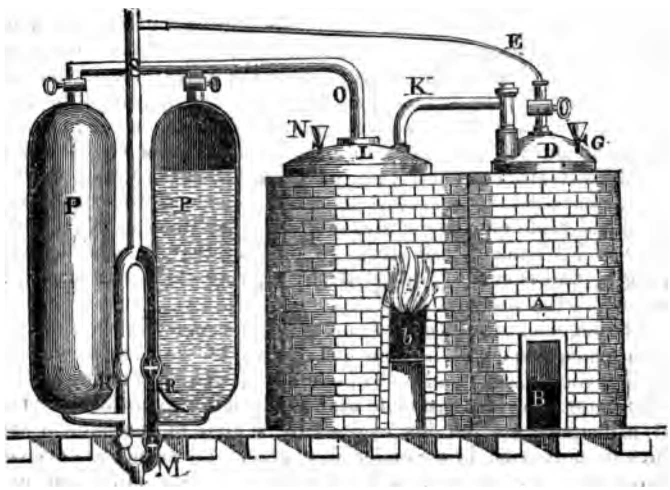
nated in the construction of an useful and ingenious machine, a description of which we will speedily give. In 1684 he had discovered the method of dissolving bones by steam of a very high pressure and temperature, and in this invention introduced that simple but inseparable accompaniment of every steam engine, THE SAFETY VALVE. This invention (without which steam would, long 'ere this, have been abandoned as a most dangerous and ungovernable agent,) entitles Papin to universal admiration; since it has contributed more than any single addition or improvement to the maturity of the steam engine.

The course of Papin's experiments occupied a number of years, and in their progress many ideas occurred to him which have since been adopted as the most important improvements. His earliest project was that of using an air pump, for the purpose of transmitting power to some distance in order to raise water where the first mover could not be conveniently applied. For instance, where a fall of water could be obtained, he proposed to erect a water wheel, which should work an air pump. This air pump he intended to connect by pipes with another pump at the place where the mine was situated. When by the crank on the water wheel the piston of one pump was depressed, the air in the pipes would be condensed, and force up the piston of the other cylinder; and when the piston of the first cylinder was elevated, that of the second would be drawn down by partial vacuum which the elevation produced. This experiment failed even in a model; and Papin directed his studies to the discovery of some means of forming a vacuum under his piston. In 1688 he described a method of effecting this by first displacing the air by exploding *gunpowder*. This he abandoned as dangerous; and, finally, after various experiments and failures, in 1690 he suggested the employment of *steam* for raising the piston, and afterwards forming a vacuum in the cylinder by its condensation. He states—" that in a little water, changed into steam by means of fire, we can have an elastic power like air; but that it totally disappears when chilled, and changes into water, by which means he perceived, that he could contrive a machine in such a manner that with a small fire he could be able, at a trifling expense, to have a perfect vacuum." After noticing the difficulty of making a vacuum by gunpowder, he observes, " where there may not be the conveniency of a near river to turn the aforesaid engine, I propose alternately turning *a small surface* of water into vapour by fire, applied to the bottom of the cylinder which contains it: which vapour forces up the plug or piston in the cylinder to a considerable height, and which, as the water cools when taken from the fire, descends again by air's pressure, and is applied to raise water out of the mine."

This, as far as discovery goes, entitles Papin to the merit of having first invented the well known Atmospheric Steam Engine: and; probably, had he followed up the idea by actual experiment, we would have had to record him as the man who first brought it into successful operation: but the greatest merit is not always due to the inventor. Thousands of the most brilliant discoveries have perished

for want of industry or talent to foster them. The man who first invents and afterwards struggles through every difficulty, and by the greatest sacrifices and perseverance brings it into actual practice, perhaps outsteps the projector of the most refined contrivance of which history can boast.

Whilst Papin was prosecuting these interesting experiments, a sea-faring man, named Captain Savery, was engaged in England, in endeavouring to bring into notice an engine of his invention, which possessed great merit. The description of his machine was published in a work of his, called "The Miner's Friend." This work is dated 1702, and contains, besides a candid detail of the principle of his invention, much useful instruction relative to the proper management of his machine. The liberality and honest appeal to experiment which pervades the whole work, forms a rare and striking contrast with the self-sufficiency and conceit which are too generally to be found in productions of this nature. Savery exhibited his model before King William, who warmly interested himself in the project. In June, 1699, he obtained a patent, granting him the exclusive privilege of manufacture. We subjoin a description nearly in the words of the inventor.



"The first thing is, to fix the engine in a good double furnace, so contrived that the flame of your fire may circulate round, and encompass your boilers, as you do coppers for brewing. Before you make any fire, unscrew G and N, being the two small *guage pipes* and cocks belonging to the two boilers, and at the holes fill L, the large boiler, two-thirds full of water, and D, the small boiler, quite full. Then screw on the said pipes again as fast and as tight as possible. Then light the fire at B, and, when the water in L boils, open the cock of the first vessel P (shown in section) which makes all the steam rising from the water in L pass with irresistible force

through O into P, pushing out all the air before it through the clack R, and when all is gone out, the bottom of the vessel P will be very hot; then shut the cock of the pipe of this vessel, and open the cock of the other vessel P, until that vessel has discharged its air through the clack R up the force pipe S. In the mean time, by the *steam's condensing* in the vessel P, a vacuum, or emptiness, is created, so that the water from the well must and will necessarily rise up through the sucking pipe T, lifting up the clack M, and filling the vessel P."

"In the mean time, the first vessel P being emptied of its air, open the cock again, and the force is upon the surface of the water, and presses with an elastic quality like air, still increasing in elasticity or spring till it counterpoises, or rather exceeds, the weight of the water ascending in S, the pipe, out of which the water in it will be immediately discharged when once gotten to the top, which takes up some time to recover that power; which having once got, and being in work, it is easy for one that never saw the engine, after half an hour's experience, to keep a constant stream running out the full bore of the pipe. On the outside of the vessel you may see how the water goes out as well as if the vessel were transparent; for as far as the steam continues within the vessel, so far is the vessel dry without, and so very hot, as scarce to endure the least touch of the hand. But as far as the water is, the said vessel will be cold and wet where any water has fallen on it, which cold and moisture vanishes as fast as the steam in its descent takes place of the water; but if you force all the water out, the steam, or a small part thereof, going through P, will rattle the clack, so as to give sufficient notice to change the cocks, and the steam will then begin to force upon the other vessel without the least alteration in the stream, only sometimes the stream of water will be somewhat stronger than before, if you change the cocks before any considerable quantity of steam be gone up the clack R: but it is better to let none of the steam go off, for that is losing so much strength, and is easily prevented, by altering the cocks some little time before the vessel is emptied."

The ingenious inventor goes on to explain minutely the ease with which his engine could be managed; however, we have quoted sufficient to shew clearly the mode of operation. He gives no proportions of the parts, nor is it probable that he himself established any rule, but principally erected his engines by a kind of mechanical tact, which he possessed in a wonderful degree. He seems to have considered that the strength of his machine was the only limit to be observed; "for," says he, "I will raise you water 500 or 1000 feet high, could you find us a way to procure strength enough for such an immense weight as a pillar of water of that height; but my engine, at 60, 70, or 80 feet, raises a full bore of water with much ease."

Captain Savery's invention shews him to have been a man of extraordinary talent and ingenuity. The real benefit which it conferred upon society was not alone confined to the reduction of animal labour: it had the effect of enabling ingenious mechanics to direct their energies to a subject which had hitherto been a matter of mere philosophical speculation. It furnished material for study; and,

though it was adopted with caution, and to a very limited extent by the mining districts; there can be no donbt but it was the means of sowing those seeds of talent which have since enabled this country to outstep every other in the superior manufacture of steam machinery.

The honourable fame which the invention obtained him could not be enjoyed without detraction. Envious contemporaries were busily engaged in endeavouring to injure, by false accusation, the character which Savery obtained. Desaguliers unequivocably asserts that Captain Savery merely put in practice the Marquis of Worcester's plan for raising water; and, the better to conceal the fact, bought up and burnt all the copies of Lord Worcester's Work on which he could lay his hands.

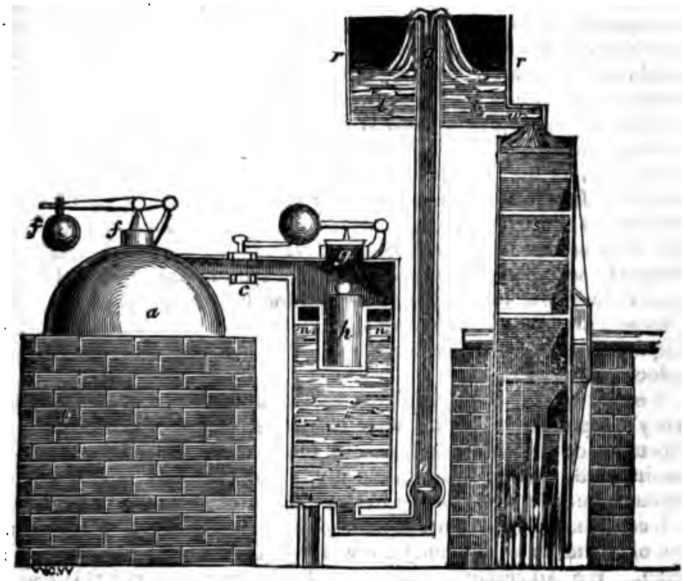
Stewart, in his History of the Steam Engine, has taken much pains to refute this grievous charge: but we shall merely content ourselves by quoting Dr. Robinson, who says,—"That the account in the Century of Inventions could instruct *no person* who was not sufficiently acquainted with the properties of steam, to be able to *invent the machine himself*." This opinion may be received without hesitation, since we have shewn that the Doctor maintained that the Marquis of Worcester was, undoubtedly, the inventor of the Steam Engine.

We quitted Dr. Papin to detail the important results of Captain Savery's experiments, which were published in the interim between the commencement and conclusion of those of the ingenious Doctor, who, in 1698, we find still persevering in his project for raising water by steam, under the patronage of the Elector of Hesse. In 1705 he received from the celebrated philosopher, Leibnitz (who had seen some of them in operation,) a drawing and description of Savery's engine. We sincerely regret that Papin ever received this communication, as it has been shewn that he had actually projected a plan which, if carried into operation, would have constituted the Atmospheric Engine, invented by Newcomen. But, unfortunately, the success of Captain Savery diverted his mind from the superior project of forming a vacuum under a piston, and by the command of his patron, the Elector, he set about to improve Savery's machine, which is universally allowed to be inferior in effect to the other. The talent of Papin, directed to the Atmospheric Engine, must have produced most important results, which, however, have been lost by the success of Captain Savery's machine.

The consequence of this course of experiment was the publication of a "new method of raising water by the force of fire," dated at Cassel, 1707. He acknowledges that Savery had hit on another mode without knowing his experiments. The following is a description of the machine.

A boiler, *a*, made of copper, communicates by a pipe with a cylinder, *i*, which forms the body of the pump. This cylinder is attached to an upright pipe *o q*, which enters the cylinder *r r*, rising to within a short distance of its top. This cylinder is air tight, and has a pipe *w*, smaller in its bore than the pipe *o q*. The pipe between the boiler and cylinder has a stop cock at *c*. *f* is the safety valve

which prevents the explosion of the boiler, by yielding to the force of the steam, and allowing it to escape when it exceeds a certain pressure, which is regulated by shifting the weight *f* on the lever. Within the cylinder is a piston or float, *n*, made of thin plates of metal, and loaded with the weight *h*, forming a part of a hollow cylinder, which floats on the surface of the water.



When a sufficient quantity of steam is generated in the boiler, *a*, the cock is opened to allow it to flow into the pump cylinder *i*, forcing the water, which is beneath it, through the pipe *o q*, until it falls at the upper end *q*, into the receiver *r r*, since it cannot flow away through the pipe *w*, so rapidly as it comes in, on account of the pipe *w* being smaller, it rises and compresses the air into the upper part of the receiver. As it escapes through *w*, it issues with velocity on the water wheel *s*, to which it gives motion in the usual manner. When the floater *n* has reached the bottom of that cylinder, the cock *c*, is shut, which prevents the further admission of steam from the boiler, into the pump cylinder, above the floater; and the valve *g* is lifted, to allow the steam above the floater to escape into the atmosphere; a vacuum speedily forms in this space, which is as speedily filled up by water from the mine, through the clack at the bottom of *i*, the clack *o* opening upwards, prevents the column of water in *o q* from descending, whilst the compressed air *r r*, keeps a constant stream on the wheel. When the floater has risen to its proper position, the steam is again admitted on the surface of the floater, and drives up the water as before.

This machine Papin published as the invention of the Elector of Hesse, but it is quite obvious that his disposition to flatter his patron,

rather than the regard to truth, caused him to make this statement. We have already expressed our regret that Papin did not persevere in his idea of the *Atmospheric Engine*. As it is, he has shewn himself to be a man of great talent and originality.

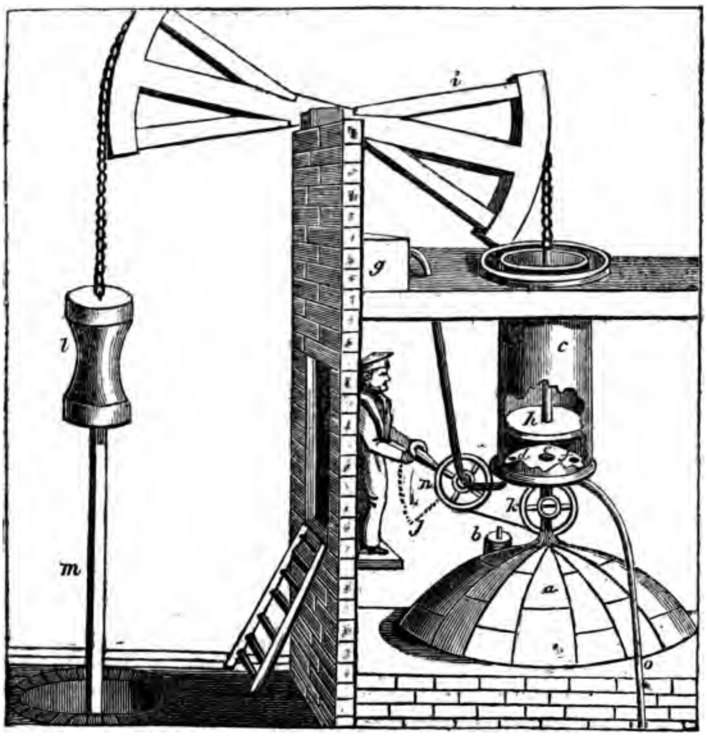
We have already observed that the beneficial effects of Savery's invention were not confined to the reduction of animal exertion. This, though a grand, was not the principal result which arose from its introduction; for the great danger, or more probably *fear*, of explosion, tended to counteract its general adoption. We say, therefore, that the greatest benefit which it created was that of familiarising all mechanics with the nature of steam; its elasticity when heated, and its "*sucking power*" when cooled: and when Savery's engine was found inadequate to the proposed end, ingenuity was on the alert to apply these in some more efficient manner. This feeling found its way to the ancient town of Dartmouth, in Devonshire, and drew forth the attention of Thomas Newcomen, a blacksmith. This man, though possessed of little scientific knowledge, was endowed with a clear head, and great inventive powers. He had been, from his childhood, fond of amusing himself with little mechanical combinations, which obtained him among his friends and companions the title of a "*schemer*." We are informed that he had seen one of Savery's engines, when he conceived the possibility of obtaining power in a manner similar to that proposed by Papin in his first project, namely, by a water wheel working two air pumps. He was so completely convinced of the feasibility of his plan that he applied to Dr. Hooke on the subject, who, it appears, dissuaded him from the prosecution, adding this remarkable and important suggestion, "If you could make a *speedy vacuum* in your second "cylinder your work is done."

Newcomen, we are informed, was for some time engrossed with the new train of ideas to which this hint led him, till at length he conceived the "*sucking and forcing*" power of *steam* would, in every respect, answer the end, and this brilliant thought he communicated so his friend and fellow townsman, John Cawley, a glazier. By joint study and exertion they soon satisfied themselves of the practicability of the scheme, and constructed the machine upon a small scale. It is not known in what manner this model was made, but we may easily imagine a very simple and cheap one could be formed by the use of a common syringe; and to such of our readers as would wish to understand thoroughly, the principle of the atmospheric engine, we recommend the following experiment:—

Into the perforation of a small glass globe, partly filled with water, introduce the mouth of a common syringe. Form a luting round the joining so as to render the joint good and tight. Apply this to the flame of a lamp, and as soon as the water boils, the steam formed thereby will force up the rod of the syringe to the top: immerse the whole in cold water, and the rod will as speedily descend. Apply the lamp again and the rod will again be raised, and upon plunging it again into cold water it will descend as before; these motions may be repeated *ad infinitum*.

Newcomen and Cawley being assured of success, were about applying for a patent, when Savery claimed the invention as his, on the ground that the method of procuring a vacuum by steam was his discovery: they were, therefore, obliged to allow his name to be associated in the grant which they obtained in 1705.

We present our readers with a novel drawing of Newcomen's engine; we are not aware that such a machine was ever in operation; but we have been favoured with the drawing by a friend, who informs us that the original bears date 1720, fifteen years after the patent was obtained. As it represents some of the parts in a singular form, and shews clearly the mode of operation, we shall offer no apology for using it in our explanation.



a represents the boiler, of which *b* is the safety valve, being a weight placed on a clack, which yields to steam above a certain pressure, and prevents explosion. *c* is the cylinder, open at the top, having three holes at the bottom, *d e f*. The hole *e* admits the steam from the boiler; the hole *d* admits a jet of cold water from the reservoir *g*, in order to expedite the condensation of the steam. *f* is a pipe for the exit of the condensed steam, and to get water from the

cylinder. *h* is the piston or plunger, whose diameter exactly fills the area of the cylinder. It is packed or stuffed on its edge, so as to preserve the vacuum as perfect as possible: *i* is the beam, or (as it is called in some of the coal districts) the *loggerhead*, for the purpose of communicating the motion of the piston to the pumps in the mine.

A sufficient quantity of steam is first formed in the boiler when the boy pushes the handle or lever which he holds down to *j*, which, by the wheels and band, opens the cock *k*, and allows the steam to enter the cylinder. The steam being only sufficient to equal the pressure of the atmosphere, will not of itself lift the piston and loggerhead; it is therefore necessary that some means should be adopted to aid it in its ascent. This is done by means of the weight or counterpoise *l*, so that by the force of the steam and gravity of the counterpoise, the piston is elevated to the top of the cylinder, and forces down the pump rod *m* into the pump in the mine. When this is effected, the boy returns the handle to its original position (shewn in the drawing) which prevents the admission of more steam from the boiler, and at the same time opens the cock *n*, so as to admit a small quantity of cold water from the reservoir *g* into the cylinder; this, by dispersing itself among the steam in the cylinder, almost instantly condenses it, so that a vacuum is obtained, and the pressure of the atmosphere meeting with no resistance, presses down the piston, and thereby raises the pump bucket in the mine. The handle is again depressed to *j*, which allows fresh steam to enter the cylinder, and elevate the piston as before. To prevent the accumulation of water in the cylinder, the pipe *o* is of such length, that a column of water within it exceeds the air's pressure, so that the water runs off by its own gravity.

The force of this engine, therefore, consists entirely of the pressure of the atmosphere, differing essentially from Papin and Savery, both of whom used the force of steam as well as a vacuum. By this method the danger of bursting the boiler was nearly obviated, as the pressure of one or two pounds on the inch on the boiler was sufficient to work the engine. The power must be regulated by the area of the piston, because, as the pressure of the air seldom exceeds 14¾ lbs. on an inch in a given area, we can never obtain more than a given power: thus, supposing the area to be 100 inches, and the pressure of the atmosphere 14 lbs. per inch, the pump piston would at each stroke lift 1400 lbs. of water at each stroke of the engine, a height equal to the length of the cylinder. This, however, is far above the real performance: as friction and imperfect condensation seldom leave more than one third of the power.

But notwithstanding the enormous loss of steam, and, consequently, fuel by these causes, we find the atmospheric or "*open topped*" engine used with different modification to a great extent even at the present day. The expense of the *double acting* engines counterbalancing, in the opinion of coal owners, the greater consumption of fuel in the other.

The engine we have given contained many improvements upon the first, the steam of which was not condensed by injection, but merely

by surrounding the cylinder with cold water. Condensation by a jet is said to have been discovered from an accidental hole in the cylinder, allowing the water which surrounded it to get into the inside, and thus the speed of the engine was doubled. When the cause of this was ascertained, the injection cock was added, as a matter of course. We should also, state, that the machine was, by no means, so simple as our drawing represents; a number of catches and springs being necessary to obtain the changes of the cocks; the uncertainty arising from the employment of boys was, likewise, a matter of much vexation and inconvenience. This evil, however, produced its own remedy; for a boy, named Humphrey Potter, being inclined to *scog*, or skulk, fastened a cord from the beam to the handle, *j*, and a weight to the handle also, by which means the engine itself produced the necessary motion. This he called a "*scogger*."

With this addition Newcomen's engine approached very nearly to a self-acting one; but still the turning of cocks and filling of reservoirs was obliged to be in part left to careless men, and as the precision of the work depended upon these, frequent derangement was the consequence; until Mr. Henry Beighton, of Newcastle-upon-Tyne, constructed what he called the hand gear, whereby motion was given to all the cocks and levers, by a rod from the beam. This engine was erected in 1718, and, besides the improvement mentioned, it was the first engine in which a *steel-yard* safety valve was used.

After the improvements of Beighton little remained to be done to the Atmospheric Engine, most of the difficulties peculiar to its construction having been overcome. We should except, however, one great evil, and that was the frequent destruction of the boiler and cylinder. This was owing to the position in which they were placed, for the piston striking against the bottom of the cylinder, frequently shook the boiler in a few days so as to completely loosen it from the brick work, and the reversion of the beam produced a violent pull in the opposite direction. The writer has seen one of these engines near Newcastle, where the top of the boiler rose and fell at least half an inch at each reversion of the stroke. This difficulty was obviated in a tolerable degree, by placing the cylinder *beside* the boiler and, thus modified; Newcomen's engine is used all over the kingdom.

We cannot conclude this chapter without expressing the veneration which we feel for the memory of the immortal Newcomen. We are bold to say (and we know, in saying this, we differ from abler and better historians) that Thomas Newcomen did more for the Steam Engine than any one individual that ever contributed to its improvement. We except none,—Watt, himself, and in the mention of that name we feel the profoundest humility,—Watt sinks into comparative insignificance when compared with Newcomen. For, whether we value the genius of a man by the extent of its utility, or by the difficulties which it encounters, and over which it triumphs, we are alike bounden to place the name of Newcomen first among those which have been the boast of our country.

CHAPTER II.

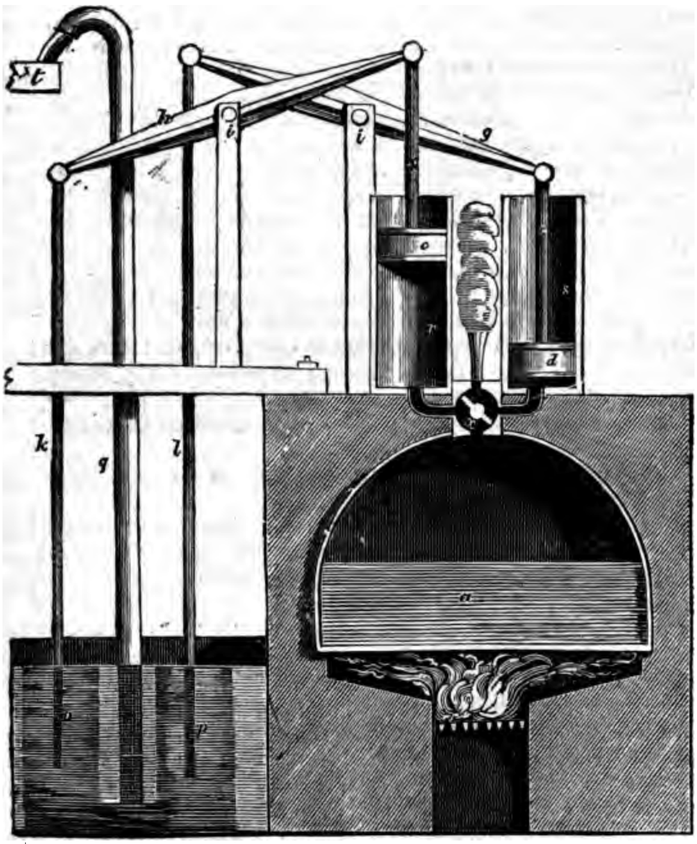
CONTENTS.—LEUPOLD'S HIGH-PRESSURE ENGINE—ADVANTAGES OF HIGH-PRESSURE ENGINES.—HULL'S PATENT.—BLAKEY AND PERKINS.—MR. KEANE FITZGERALD'S SUBSTITUTE FOR THE CRANK.—WATT'S EXPERIMENTS.—GAINSBOROUGH'S CLAIMS TO WATT'S INVENTION —CYLINDER OF WATT'S ENGINE.—SUN AND PLANET MOTION.—PARALLEL MOTION —GOVERNOR.—CONDENSER.—WATT'S EXPERIMENTAL ENGINE.—COUNTER.—ADDITION OF THE CRANK AND SUBSTITUTION OF THE SUN AND PLANET MOTION.

In the year 1720 the celebrated Leupold constructed *the first high-pressure engine.* Previous to this the only use to which steam had been effectively applied was in the formation of a vacuum: true it is, that in the projects of De Caus, Branca, and Savery, the elastic force of steam was proposed to be used; but the failure of these plans by waste of steam and other causes, warrant our saying that the plan of Leupold entitles him to the great merit of having *invented and constructed the first high-pressure engine.* His principle was simply that of applying highly elastic steam alternately upon two pistons in separate cylinders, so that as one ascended the other descended, and vice versa.

In the annexed figure (nearly resembling that given by Leupold) the boiler *a*, communicates by a "*four way cock,*" with the bottom of two *open topped* cylinders having pistons *c d* moving in them. These pistons are fitted with lead so that they may act as a counterpoise to the pump buckets *o p*. They are likewise attached to the beams *g h*, by means of the rods *e f*. To the other ends of the beams are fixed the pump rods *k l*, which work two force pumps *o p*. *q* is a perpendicular pipe, bended round at the top so as to convey the water driven up the pipe into the cistern or spout *t*. *i i* are the centres of the two beams *g h*. *x* is a cock so constructed as to alternately admit the steam into either cylinder.

In the situation of the machine shewn in the figure, the steam in the boiler flows through the open passage into the cylinder *r*, and presses the piston *c* upwards: this depresses the pump rod *k*, and forces the water under the plunger, up the pipe *q*. When the steam has raised the piston *c* to nearly the top of the cylinder, the cock *x* is turned one fourth of a revolution, so that it opens a passage between the cylinder *s*, and the boiler; and between the cylinder *r*, and the open air. The weight of the rod *f*, and the lead in the piston *c*, being greater than *k* and *o*, the piston descends by its gravity to the bottom of the cylinder, driving out the steam which raised it into the atmosphere. From the construction of the "*four way cock*" at the moment in which the passage into the cylinder *r* was closed, another passage was opened between the boiler and cylinder *s*; the elasticity of the steam forces the piston *d* upwards, and depresses the plunger at the end of the rod *l*, and impels the water, in the barrel *p* under it, up the pipe *q*. When the piston *d* has reached the top of

the cylinder, or made its stroke, the further passage of steam from the boiler is shut off, by turning the cock *x*; and the steam escapes into the atmosphere through *z*; and *d* descends in the cylinder by its preponderance in the same manner as *c*. During the ascent of *d*, *c* has fallen to the bottom of the cylinder *r*. The steam passage from the boiler being then opened, *c* is again raised in its cylinder, while the vapour in *s* is escaping into the atmosphere; thus producing an alternate vertical motion in the pump rods *k l*.



Such was the construction of the first high-pressure engine, which for simplicity has never been exceeded. The extended use of such engines at the present day, proves that the public opinion is materially changed in regard to their utility and safety. The risk of explosion was a drawback upon them, which successive improvements and skilful management has almost annihilated; and we have no doubt but that, eventually, the low-pressure or condensing engine will be entirely

abandoned in favour of those. Their superior economy by reduced consumption of fuel, and reduced friction, are sufficient grounds for their general adoption. We should observe, however, that there is still a mass of prejudice to contend with, ere this can possibly take place, and whilst America has scarcely a low pressure engine to work a steam boat, it would be a hazardous speculation to attempt the introduction of a high-pressure one in England for that purpose.

But from the importance which the latter does, and will maintain, in the mechanical world, it will not be amiss to shew the advantages which they possess: and we shall first speak of that obtained by a saving of fuel.

Water does not boil under a temperature of 212° of Fahrenheit, at which temperature its force, when confined, is barely equal to that of the atmosphere. But let the temperature be increased only 38° more, (which can be effected with a comparatively small addition of fuel) and its force will be 28 lbs. on the square inch. In like manner let the temperature be increased to 280°, and the force will be equal to 56 lbs. Thus, the increased force far exceeds the increased consumption of fuel, and, consequently, the greater the pressure of the steam, the greater will be the saving. Recent experiments have proved that steam, when heated to 1170°, will act with a force of 56,000 lbs. on the square inch, so that we find 250° gives a force of only 28 lbs. whilst rather more than four times that temperature, or 1170°, gives 2000 times the force; a fact sufficiently establishing the superior economy of high-pressure steam.

It should be observed, however, that we by no means believe that such pressure can be used with safety; but we merely state the fact to establish the position that high-pressure engines are more economical than low-pressure ones.

The saving of power, by reduced friction, is also another material advantage in the former, because it is evident that if a force of 50 lbs. be obtained per square inch for 10 or 12 in the condensing plan, the area of the piston will be smaller in the same proportion as the force is increased, in order to produce a given effect; therefore, the edges of the piston being reduced also, there will be less rubbing surface than in the other.

Hitherto steam had been only employed in raising water, nor had any plan been devised by which it could be adapted to the giving motion to machinery; Savery, indeed, says his machine might be applied "to mills of various kinds and forms, according to the different genius and abilities of the millwright;" and that "it may be brought to work by a steady stream," (on a wheel), "and produce a rotative or circular motion;" and hints, that it might be made very useful in ships, but he dare not meddle with that matter; and leaves it to "the judgment of those who are the best judges of *maritian* affairs;" but since Savery's machine itself failed, of course the projects perished with it. After the important improvements of Newcomen, it will appear evident that any effectual method must be very different from this; and, accordingly, we find a patent taken out in 1736, by Mr. Jonathan Hulls, of London, "For a new-in-

vented machine for carrying vessels or ships out or into any harbour, port, or river, against wind or tide, or in a calm." This new method was the application of the crank which now, it is well known, enables us to employ the steam engine as a prime mover in almost every species of machinery.

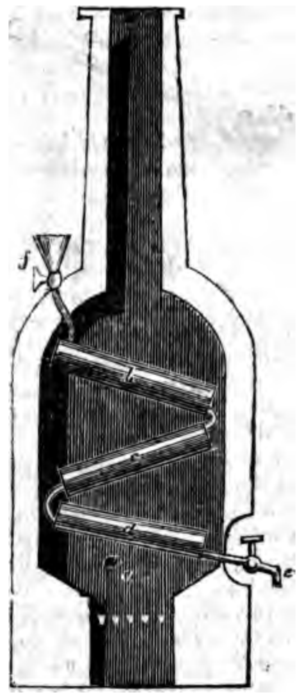
Unfortunately, the public mind was not sufficiently matured to interest itself in the project, and, in consequence, Hulls and his patent were so completely forgotten, that the invention has been susbsquently claimed by Watt.

We should here observe, however, that whilst we give due praise to Hulls for the greatness of his project, we feel satisfied that Newcomen's engine was not at all adapted to the proposed combination; as the great difference in power between the ascending and descending stroke of the piston would have required a ponderous fly wheel to have any thing like equality of motion, and a fly wheel would be an inconvenient accompaniment to a steam boat. The idea, however, was great, and the ingenious inventor deserved better success than he obtained.

We should not omit in this place to notice Blakey's patent, in 1766, for improvements on Savery's method of raising water. To avoid condensation he proposed to introduce oil on the surface of the water, because oil did not so readily absorb the caloric: but his principal improvement consisted in the boiler, which was formed of small tubes, completely filled with water. The proposed improvements drew forth the attention of almost all the scientific men of his day, many of whom declared it possible to conduct the influence of steam to the centre of the earth. "But," says Hornblower, "an accident terminated the event as to the experimental engine, by one of the steam vessels bursting through the force of steam, though much under the degree of power proposed by the Cornish gentlemen. Such," continues Hornblower, "is the degeneracy of man, that whilst the States General of Holland were pluming Blakey with the gaudiest expressions of approbation, not one instance is to be found, in which he met with that support he had been led to anticipate."

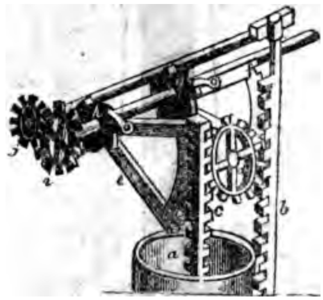
The drawing here given exhibits Blakey's boiler, or generator, the principle of which, our readers will observe, has been renovated in Perkins's recent attempts. The success attendant upon the renovation has fallen short of calculation, but this has been owing rather to the mode of application than to the generator itself, which for safety and portability never will be surpassed. The cause of Perkins's failure we shall notice in its proper place.

a represents the furnace in which the tubes, *b c d*, are placed, which are connected by small pipes; *f* is a funnel for supplying the generator with water. This was the ancient mode of supplying all boilers, but it is needless to observe, that since the addition of the force pump, the former has been unnecessary. *e* is a cock, for the purpose of cleaning the boiler, by running water through the whole. The pipe which connects the generator with the engine is not shown.



Mr. Keane Fitzgerald, a gentleman of great scientific acquirements, and whose ingenious discoveries stand recorded in the Philosophical Transactions, describes, in the year 1758, an invention, by which he proposed to obtain a rotatory motion from a rectilineal one, in another way than by the crank, the application of which was unknown to him. No drawing has ever been given, and we therefore give the accompanying sketch, which we gather from the words of the inventor: they are as follow.—

"A rotative motion may be obtained from a rectilineal one, by employing a combination of large toothed wheels, and of smaller ratchet wheels, worked by teeth upon the arch or sector of the beam, one of these ratchet wheels being put in motion by the ascent of the beam, and standing still during the descent, when another ratchet wheel is moved by an intervening wheel in the same direction as the first; and thus the two communicate a continuous rotative motion to the axis upon which they are placed, which is thence transmitted by a large toothed wheel to a smaller wheel or pinion, on the shaft of which is *a fly to accumulate momentum*, and crank proposed to be applied to work ventilators, and to many other useful purposes. The fly, by accumulating in itself the power of the machine during the time it was acted upon, would continue in motion, and urge forward the machinery whilst the steam engine was going through its inactive returning stroke."



Let *a*, then, represent the cylinder on the principle of Newcomen; *b c*, two racks, of which *c* is the piston rod; these racks are toothed on two angles, two for the purpose of being moved by, and giving motion to the connecting pinion, *d*, and the remaining two for the purpose of working the sectors, *c f*; these sectors have palls or catches fixed on each of them, which are situated so as to fall into the teeth of the ratchets, *g h*. We will now suppose the piston rod or rack, *c*, to be ascending: then the catch on the arm of the sector will turn round the ratchet, and the axle upon which it is fixed, a portion of a revolution. This motion will be continued until the piston has reached the top, when the pall of the sector, *f*, falls into the next tooth of the ratchet. The motion of the piston is now reversed; but by the intervention of the pinion, *d*, the rack, *b*, begins to ascend, and repeats the same operation upon the ratchet, *g*, as the other sector did upon *h*: thus, the two sectors alternately act upon the ratchets, and keep the axle in a continuous rotative motion; this motion is communicated to another axle by the wheels, *i j*: on the latter axis a fly is fixed, which preserves the motion equable and regular.

We admire the ingenuity of this invention, although we are satisfied it would never answer the proposed end. The principal objection would be that of the piston striking violently the top and bottom of the cylinder; because, as the motion of the fly is obtained from the direct action of the piston rod, any decrease of speed in that must likewise decrease the speed of the fly-wheel, and therefore produce an irregular motion. Not so the common crank, which naturally retards the motion of the piston, as it approaches the top and bottom of the cylinder, whilst itself revolves at the same speed throughout.

We now come to the most important era in our history: that in which James Watt commenced his invaluable exertions in the improvement of the Steam Engine. It is not in our plan to give biographical sketches of the inventors who come under our notice; but as the beginning and progress of Watt's career form some of the principal events of his life, our history must here assume somewhat of this character.

James Watt was born in Greenock, in the year 1736. He was,

at the age of 16, apprenticed to a mathematical instrument maker. This business, it appears, differed materially from what we now understand by the term, consisting of land-surveying, making and repairing clocks, almost every kind of musical instruments, fishing tackle, and cutlery. In the year 1757 he was appointed mathematical instrument maker to the University of Glasgow, and apartments were given him in the college, in which he lived and transacted his business.

It appears that at this period the college of Glasgow possessed apparatus and funds by which they were enabled to contribute largely to the general diffusion of useful knowledge among that class of individuals to whom it was peculiarly beneficial. This was one among the many advantages which arose from the establishment, but the greatest was that of exciting the attention, and drawing forth the energies of young Watt. We shall give the particulars of the commencement of his career in his own words, being satisfied that we cannot exceed them either in simplicity or effect.

—" My attention," says he, " was first directed in 1759, to the subject of steam engines, by Dr. Robison, then a student in the University of Glasgow, and nearly of my own age. Robison at that time threw out the idea of applying the power of the steam engine to the moving of wheel carriages, and to other purposes; but the scheme was not matured, and was soon abandoned on his going abroad."

" In 1761 or 1762 I made some experiments on the force of steam in a Papin's digester, and formed a species of steam engine, by fixing upon it a syringe one third of an inch in diameter, with a solid piston, and furnished also with a cock to admit the steam from the digester, or shut it off at pleasure, as well as to open a communication from the inside of the syringe to the open air, by which the steam contained in the syringe might escape. When the communication between the cylinder and digester was opened, the steam entered the syringe, and, by its action upon the piston, raised a considerable weight (15 lbs.) with which it was loaded. When this was raised as high as was thought proper, the communication with the digester was shut, and that with the atmosphere opened; the steam then made its escape, and the weight descended. The operations were repeated; and (though in this experiment the cock was turned by hand) it was easy to see how it could be done by the machine itself, and to make it work with perfect regularity. But I soon relinquished the idea of constructing an engine upon this principle, from being sensible it would be liable to some of the objections against Savery's engine; from the danger of bursting the boiler, and the difficulty of making the joints tight; and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston."*

* The reasons here given by the historian will appear, to modern mechanics, very futile and insufficient. It is now a matter of *no* " difficulty to make the joints tight;" and high-pressure steam, it is well known, is more economical than that at which Mr. Watt worked his engines.

The attention necessary to his business of a mathematical instrument maker, prevented him from prosecuting the subject any further at this time. But in the year of 1763-4, having occasion to repair a model of Newcomen's engine, belonging to the Natural Philosophy Class of the University, his mind was again directed to the subject. At this period his knowledge was derived principally from Desaguliers, and partly from Belidor. He set about repairing the model *as a mere mechanician*, and when that was done and set to work, he was surprised that its boiler was not supplied with steam, though apparently quite large enough (the cylinder of the model being two inches in diameter and six inches stroke, and the boiler about nine inches in diameter); by blowing the fire it was made to take a few strokes, but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred to him that this was caused by the little cylinder exposing a greater surface to condense the steam than the cylinders of larger engines did, in proportion to their respective contents; and it was found that by shortening the column of water, the boiler could supply the cylinder with steam, and the engine would work regularly with a moderate quantity of injection. It now appeared that the cylinders being of brass would conduct heat much better than the cast iron cylinders of larger engines (which were generally lined with a strong crust), and that considerable advantage could be gained by making the cylinders of some substance that would receive and give out heat the slowest.* A small cylinder of six inches diameter and twelve inches stroke, was constructed of wood, previously soaked in linseed oil, and baked to dryness. Some experiments were made with it; but it was found that cylinders of wood were not at all likely to prove durable, and that the steam which was condensed in filling it still exceeded the proportion of that which was required in engines of larger dimensions. It was also ascertained, that unless the temperature of the cylinder itself were reduced as low as that of the vacuum, it would produce vapour of a temperature sufficient to resist part of the pressure of the atmosphere. All attempts, therefore, to reduce by a better exhaustion, by throwing in a greater quantity of injection water, was a waste of steam, for the larger quantities of injection cooled the cylinder so much, as to require quantities of steam to heat it again, out of proportion to the power gained by having made a more perfect vacuum; and on this account the old engineers acted wisely in loading the engine with only six or seven pounds weight on each square inch of the piston.

It appears by Dr. Ure, that Watt tried some experiments regarding the latent heat of steam, of which the Doctor gives the

* The inventor was right in proposing to use some material which would receive and give out heat the slowest, but greatly in error when he supposed *polished surfaces* would conduct heat quicker than rough ones. It has been repeatedly proved, that rough surfaces are best adapted to give out or receive heat, the unevenness of the surfaces acting like an immense number of conductors to and from the metal.

following account :—" In some conversations with which this great ornament and benefactor of his country honoured me a short period before his death, he described, with delightful *naiveté*, the simple but decisive experiments by which he discovered the latent heat of steam. His means and leisure not then permitting an expensive and complete apparatus, he used apothecaries' phials: with these he ascertained the two main facts, first, that a cubic inch of water would form about a cubic foot of ordinary steam, or 1728 inches; and that the condensation of that quantity of steam would heat six cubic inches of water, from the atmospheric pressure to the boiling point. Hence he saw that six times the difference of temperature, or fully 800° of heat, had been employed in giving elasticity to steam, and which must be all subtracted before a complete vacuum could be obtained under the piston of a steam engine."

The great experimentalist deserves as much praise for these experiments as for any thing he ever effected. Upon the facts developed in this enquiry, he built up the theory which shall carry his name to posterity. Although he modestly ascribes his discovery to Dr. Black's explanation of his *theory of latent heat*, there can be no doubt that these experiments were more decisive and useful than any theoretical explanation could possibly be.

He found, therefore, that his first business was to keep the cylinder as hot as possible, and that to obtain a tolerable vacuum, the temperature of the condensed steam should be at most 100°, and less if possible. Various were the means which were contemplated to effect these ends, when, early in 1765, it struck him, "*that if a communication were opened between a cylinder containing steam, and another vessel which was exhausted of air and other fluids, the steam, as an expansible fluid, would immediately rush into the empty vessel, and continue to do so until it had established an equilibrium; and if that vessel were kept very cool, by an injection or otherwise, more steam would continue to enter until the whole was condensed.*"

So far we have the invention complete; but still the condensed water and *incondensible* steam were not disposed of, and how to rid the condenser of these was long a matter of difficulty. The water, indeed, could be allowed to run off, by having a pipe whose length would exceed that of a column of water equivalent to the pressure of the atmosphere, but the air was not removed. At last it occurred to him that a pump would draw off both air and water, and preserve a perfect vacuum in the condenser.

Thus was completed one of the greatest inventions ever known. By the simple operation of thought, in a few days was effected that which had hitherto been deemed an impossibility—*a hot cylinder and a perfect vacuum.*

We should act unfairly if we concealed that Mr. Watt has been denied, by some men of great respectability, the merit of discovering the separate condenser. Hornblower says, " It occurred to Mr. Gainsborough, the pastor of a dissenting congregation at Henley on Thames, and brother to the painter of that name, that it would be

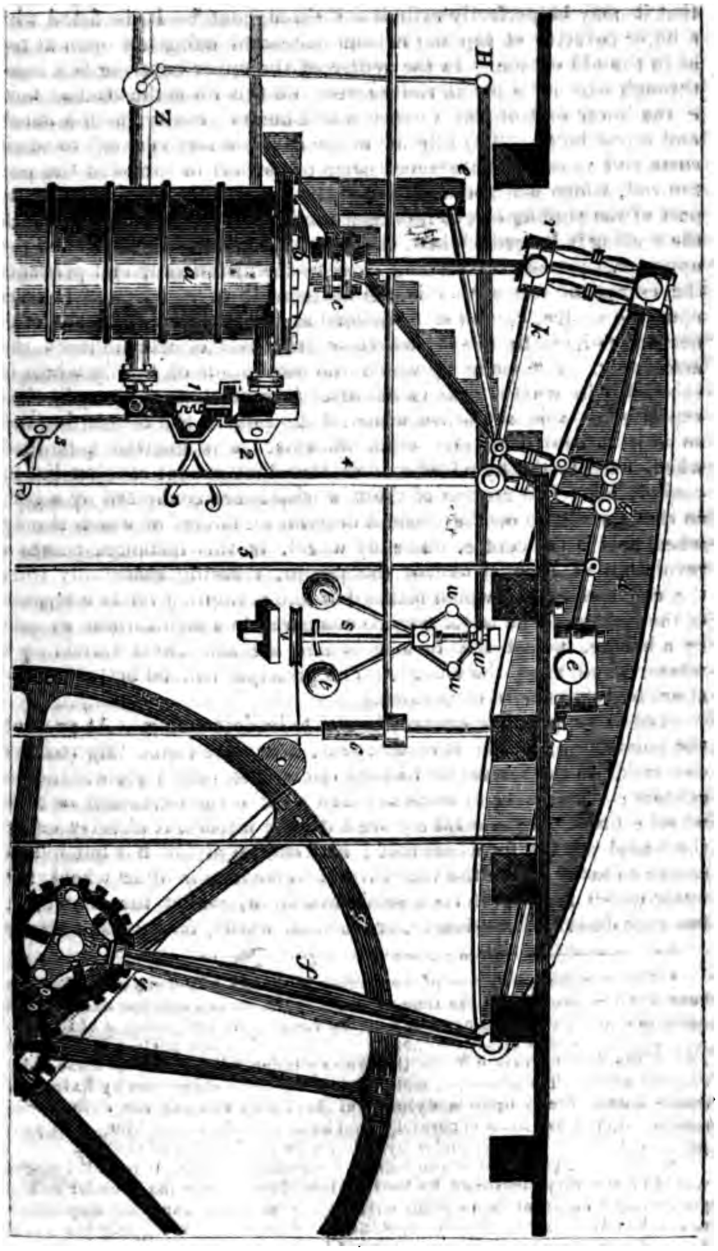
a great improvement to condense the steam in a vessel distinct from the cylinder where the vacuum was formed; and he undertook a set of experiments to apply the principle he had established, which he did, by placing a small vessel by the side of the cylinder, which was to receive just so much steam from the boiler as would discharge the air and condensing water, in the same manner as was the practice from the cylinder itself in the Newcomenian method, that is, by the shifting valve and sinking pipe. In this manner he used no more steam than was just necessary for that particular purpose. The circumstances as here relate receive some confirmation, by a declaration of Mr. Gainsborough, the painter, to Mr. J. More, late secretary to the Society of Arts, who gave the writer of this article the information. Whether he clothed the cylinder as Mr. Watt does is uncertain: but his model succeeded so well, as to induce some of the Cornish adventurers to send their engineers to examine it; and their report was so favourable as to induce an intention of adopting it. This, however, was soon after Mr. Watt had his Act of Parliament passed for the extension of his term; and he had at the same time made proposals to the Cornish gentlemen to send his engine into that country. This necessarily brought on a competition, in which Mr. Watt succeeded: but it was asserted by Mr. Gainsborough, that the mode of condensing out of the cylinder was communicated to Mr. Watt by the officious folly of an acquaintance, who was fully informed of what Mr. Gainsborough had in hand."

At this date it is impossible to decide the merits of their respective claims. It does not appear that much credence has been given to the statement of Hornblower by recent writers, but we certainly consider that it throws considerable doubt upon the matter. We by no means think with Dr. Brewster that Hornblower's ignorance of these circumstances, when examined before the House of Commons, precluded the possibility of his knowing them afterwards. But there is so much detraction where there is merit, that we sincerely hope this solitary testimony is dubious, especially when we consider that Mr. Hornblower was a rival of Watt during the whole of his career.

It should likewise be observed, that the addition of a pump to the condenser is never disputed to be the invention of Watt, and this is essential to its utility. One only instance have we known of a condenser without an air-pump, and the engine went very irregularly.

The drawing before us represents Watt's engine, with nearly all his improvements, and exhibits it in a state of perfection to which it was only brought at a late period of his life. It serves our purpose better to explain his successive alterations and additions in this way, than to give separate and unconnected diagrams, which would but convey to our readers an obscure and indefinite idea of their arrangement. We shall first proceed to explain the principle of this machine, and afterwards detail the dates of the improvements as they were added.

Our readers must suppose the cylinders, *a*, to resemble that of Newcomen's engine, excepting that it is more accurately bored, so



that it may be perfectly cylindrical throughout.* It is fitted with a lid or covering at top and bottom instead of being left open at top as in the old engine. In the centre of the upper covering is a hole, through which the piston rod passes; on this lid is the stuffing box, *c*, the lower part of which consists of a hoop or cavity, with a flanch and screw holes. The interior of the cavity is large enough to admit some soft vegetable substance (hemp or cotton) to surround the piston rod, which is likewise accurately turned. The covering or upper part of the stuffing box is less than the interior of the cavity in which the stuffing is lodged; when, therefore, the screws are tightened the upper part presses the stuffing close to the piston rod, and prevents the escape of steam.† *d* is the beam made of cast iron. It rests upon the centre, *e*, and is connected at the further end by the connecting rod, *f*, to the fly wheel, *g*, the axis of which drives the machinery. The mode by which the revolution of the fly wheel is effected is by what is called a *sun* and *planet* motion, and may be thus explained:—*h* is a toothed wheel, bolted on to the connecting rod so that it cannot revolve upon its axis. *o* is likewise a toothed wheel fixed to the fly wheel axis so that they cannot revolve but in conjunction. The centres of the two wheels are connected by a bar, so that the centre of the wheel *h* describes a circle, of which the fly wheel axis is the centre. The fly wheel, in this instance, makes a revolution at each stroke of the piston, differing essentially from the common crank, which makes but one revolution for two strokes of the piston. The latter may be compared to a man turning an axle by a handle, whilst the former is like the same axle turned by a wheel, *fixed* upon the handle. The principle will be better understood by reference to our drawing.

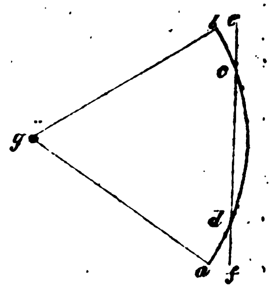
Let us suppose the connecting rod to be descending. At present the points, *o o*, are in contract: but, when the connecting rod has descended to the lowest part of its circle, the points *q q* will be in contact; the number of teeth between *o* and *q* corresponding in each wheel; but this cannot take place until the wheel *h* is directly under the wheel on the fly wheel axis; and as the piston has but half a stroke to make before the wheel *h* will be under the other wheel, the latter wheel must perform a semi-revolution, whilst the centre, *h*, has only described one-fourth, or, in other words, for each half stroke

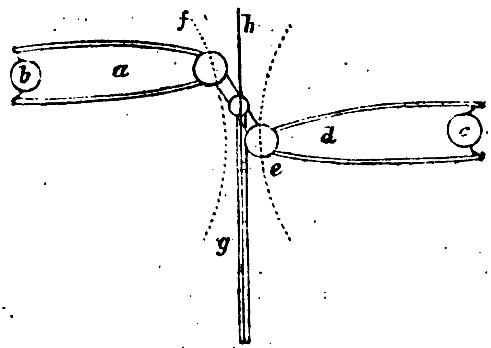
* This required a degree of perfection in the art of boring which had not been attained previous to the time of Watt. The method hitherto adopted had been to depend upon the accuracy of the casting for the guidance of the cutter, and as this was either frequently untrue, or in some parts softer than in others, the boring varied from the true cylinder when either of these mischances arose. The improved method obviated these objections by fixing the cutter block firmly upon a cylindrical bar, and causing the cylinder to resolve after it had been accurately chucked, and the cutter block was propelled the length of the cylinder by a screw in the interior of the bar.

† Mr. Watt proposed to use leather for stuffing. This, it is well known, would be speedily destroyed by heat. Hornblower made the blunder of his great rival a constant theme of his wit, and so far did he carry his disposition so laugh at Watt, that in his own specification he said, "*The stuffing box would be filled with some soft substance, but not leather.*"

of the piston : and a whole revolution for each stroke thereof. The advantages of which are, that the fly wheel makes twice the number of revolutions by this method, than it would by the common crank; so that a lighter fly wheel is required; besides which, it is extremely convenient where a rapid motion is necessary. There are, however, several disadvantages attending it, among which may be enumerated those of its being less simple, more expensive, and more easily deranged.

h e m is the parallel motion; the purpose of this is, to keep the piston rod perpendicular, whilst the end of the beam (to which it is attached) describes a segment of a circle. *e f* represents the motion of the piston rod, and *b c d a* the motion of the end of the beam, the centre of which is at *g*. The points *c d* are the only parts where the two motions coincide; and it would be impracticable to connect a piston rod, whose movement is rectilineal, with the end of a beam whose movement is curvilineal, except by a rack and sector. This was tried, and found extremely objectionable, and finally gave way to the parallel motion.





The following explanation will inform our readers of the principle of all such parallel motions. *a* represents a beam, of which *b* is the centre, and *c d* another beam of equal length. *e f* is a rod joined to the end *e* of the beam *d*, and the end of the beam *f* of the beam *a*. The piston rod *g* is attached to the middle of the piece *e f*; and as the beams are of equal radii, therefore the versed sizes are equal, but in opposite directions, so that they correct each other; for when the end *f* of *e f* is at any given distance from the perpendicular line *g h*, the lower point *e* of *e f* is drawn the same distance from the perpendicular in the contrary direction; and thus the centre of the piece *e f* will always remain in the parallel line *g h*.

Though we may thus illustrate the principle of the parallel mo-

tion, yet this method is seldom or never adopted; as it requires much extra room, because the beam *c d* being half the length of the main beam, the engine house must, to admit it, be nearly one half longer than is required for the beam alone. The form generally preferred, is that given in our connected drawing, to which we will refer. The piston rod is attached by pivots to the end of the rod or rods *r*, which are also connected by pivots to the end of the beam. The rods *g m* are of equal length with those attached to the piston, and turn upon similar pivots on the beam. These rods are connected by the bridle *k*, so that the ends of *m* and *r* describe a similar line when in motion. The beam or rod *e m* is equal in length to the part of the beam *e g*, so that *e g m e* would separately exhibit the same appearance, and produce the same effect as would the apparatus exhibited in our last diagram: that is to say, there is a point in *g m* which describes a rectilineal motion. We have already shown, that by the rod *k*, the pieces *g m* and the pieces *r* must act in conjunction, so that if a parallel motion is obtained in *g m*, it must likewise be obtained in *r*. To that part of *r* the piston rod is attached, and is thereby kept parallel during the ascent and descent of the beam.

The governor or pendulum, *s*, is used for regulating the quantity of steam admitted into the cylinder, and may be easily understood. The balls are heavy, and rise or fall according to the speed. When the engine goes too quickly, they also revolve with equal rapidity; and in doing so, the balls from their centrifugal force being increased, recede from the centre, and thereby raise the levers by which they are suspended; these levers are connected with the shorter ones, *u u*, which, in expanding, cause the ring or strap, *w*, to descend. Into a groove of this ring a fork or semicircle is made to fit, which fixed to the end of the lever, *w* H, so that as much as the strap ascends the further end of the lever descends, and by the rod, H Z, depresses the handle of the throttle valve, Z, which is a vane in the interior of the steam pipe, of such dimensions as to completely fill the pipe in one position, and by presenting its edge to the steam in another, to oppose no resistance to the entrance of the steam.

We must now return to the cylinder and condenser, the latter of which is not shewn, but may be briefly described. It consists of a tube immersed in cold water, and connected at the bottom by a pipe to a pump, which is worked by the rod, 4. The use of this pump is to preserve the vacuum by drawing off uncondensed vapour and the water of injection. It acts precisely on the same principle as the common air pump, and bears the same name, the receiver being the condenser, and the pump similar in both. We will now suppose steam admitted from the cylinder: a valve, called the *blowing valve*, is opened, which permits the steam to enter the cylinder and condenser, and drive out the air. When the air is expelled, which may be known by the crackling noise and ebullition which takes place in the water, (the former arising from the globules of pure steam rapidly condensing, and the water thereby collapsing), the blowing valve is shut, and the valves arranged so that the steam can enter the upper

part of the cylinder. The steam acting in conjuction with the vacuum now formed on the lower side of the piston causes it to descend to the bottom. The lever, 1, is now turned downwards, and shuts that valve, whilst 2, on a pipe behind that which we see, opens a passage to the condenser. The lever, 3, is at the same time opened, admitting the steam under the piston, which consequently ascends. In the act of rising, a jet of cold water is admitted into the condenser, which expedites the condensation. There are a number of tappets on the pump rod, 4, which repeat the changing of the valves when the engine is left to itself. The water in the reservoir surrounding the condenser would be soon heated by the steam, but that a pump worked by the rod, 5, keeps a constant supply of cold water from the well. 6 is a small pump, which supplies the boiler with water from the heated water drawn out of the condenser.

Having now explained the mode of operation, we have to state that the first engines were used for pumping water, and for that purpose alone. The first engine, therefore, was like Newcomen's, a single acting one, as its power was only exerted in one direction, It was covered at the top like the double engine, but instead of having the steam and vacuum to aid it in both ascent and descent, the vacuum was only used in the descending stroke of the piston, whilst the ascending one was effected by a heavy weight or counterpoise at the further end of the beam. During the latter operation the steam was admitted by a valve from the *upper* to the *under* side of the piston, and was there used for forming the vacuum below. By this method the air was entirely excluded from the cylinder.

The first engine was of this description: it was erected on the estate of the Duke of Hamilton, at Kenneil, about a mile from Borrowstoness, in Scotland. The cylinder was 18 inches in diameter, "and it was successively altered and improved, until it was brought to considerable perfection." In 1768 and 9 a patent was procured for the invention; and in conjunction with Dr. Roebuck, (the founder of the Carron Iron Works, and through whose interests the experimental engine had been erected at Kenneil) arrangements were made to manufacture on a large scale, when, from pecuniary embarrassments, the Doctor was obliged to withdraw his promised aid, and Watt was about to abandon his project, It fortunately happened, however, that a negociation was opened with Mr. Matthew Bolton, of Birmingham, which was concluded in 1773.

From this time things went on successfully; his colleague was a man of wealth and influence, and lent his utmost aid to the extension of the sale, which was effected with great difficulty, chiefly arising from the increased cost of erection. The patentees erected the engines at such prices as could be obtained, and received a third part of the saving of coal, which saving was decided by a machine similar to that now used on Waterloo, Southwark, and Vauxhall bridges. It consisted of a train of wheel work, which was moved at each stroke of the beam, and, of course, it could be easily ascertained how many strokes had been made in a given time.

In the early engines a rack and sector were used for the purpose

of working the beam by the piston; but this was very defective, and easily disarranged, especially when the direction was reversed. This gave way to the parallel motion: one of the brightest thoughts which ever occurred to Mr. Watt.

Another difficulty was the irregular motion of the engine, which was subject to considerable variation in speed, as the supply of steam in the boiler varied. This was obviated by the governor acting upon the throttle valve, which, we have already shewn, admitted more or less steam, as the speed decreased or increased. The governor was not Watt's invention, but had been previously used in corn mills, which were subject to similar irregularity. When the stones moved too quickly, the meal, by the rise of the stones, was too coarse, when on the contrary, the motion was slow, the meal produced was small in quantity and too fine. The governor, or as it was then called the *tent-lifter*, brought the mill stones nearer when in rapid motion, and removed them further off when slow. This ingenious regulator was applied by Mr. Watt to his throttle valve, and has been ever since used for that purpose.

Mr. Watt in 1778 states, that he contemplated the practicability of obtaining a rotative motion from the reciprocating one, and for this purpose he thought of the crank (for which we have seen Hulls had previously obtained a patent, but which was unknown to Watt), and when he had nearly brought his project to bear, and was about taking out a patent for it, he found that a Mr. Wasbrough, of Bristol, had already obtained a patent for the crank; Mr. Watt therefore finding himself thus prevented from using his invention, set about something which might answer the purpose instead. This he effected by his sun and planet wheel, which possesses, as we have said, some advantages over the other.

Thus we have briefly described the successful application, and the bringing into general adoption, this nearly perfect machine. We conclude this chapter by observing, that although there is scarcely a week passes without a patent being taken out for an improvement in the steam engine, it has undergone little positive amendment. The faults have been little removed by all the talent and industry exerted for the purpose; but these defects, and the attempts to remove them, we shall explain in the following chapters.

CHAPTER III.

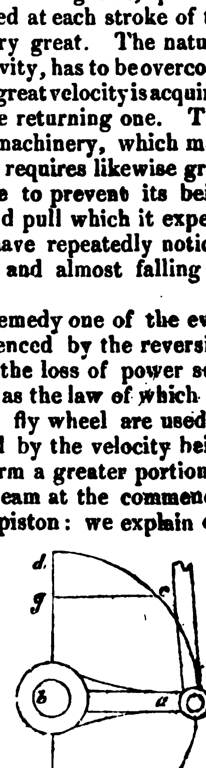
CONTENTS.—DEFECTS OF BOLTON AND WATT'S ENGINE.—FRICTION—RECIPROCATION—POWER OF THE CRANK—NO POWER LOST THEREBY—IRREGULAR WEAR OF THE PISTON ROD AND CYLINDER.—DISADVANTAGES ATTENDING THE USE OF TWO ENGINES WITH THE CRANKS AT RIGHT ANGLES WITH EACH OTHER—WATT'S ROTATORY ENGINE—WATT'S SEMI-ROTATIVE AND ROTATIVE ENGINES—BRAMAH'S REMARKS ON WATT.

We now come to speak of the imperfections attendant on the Bolton and Watt engine: these are, friction from the rubbing of the moving parts against each other—the reciprocation of the machinery, and the irregularity of the motion: we shall notice them successively. 1st, The rubbing of the parts against each other.—This evil must exist in every conceivable form into which the steam engine may be modified, but no doubt the quantity may be considerably reduced. The steam, in order that we may have its full effect, acts against a moveable piston in a cylinder from which it cannot escape. This piston is, as has been explained, packed or stuffed on its edges, which prevents the steam from escaping past it; and from the nature of the material used for packing, and the tightness with which it is pressed against the cylinder the friction arises. This is sometimes so great, that we have seen engines where the whole force of the steam could not give them motion. It is usually estimated at one third of the power of the steam—that is to say, if the steam acted upon a piston with a force of 1500 lbs., the effect produced would not exceed 1000 lbs., a power of 500 lbs. having been absorbed by the movement of the machinery alone.

The next objection is the reciprocation of the parts. This is an evil of considerable magnitude. It originates from an inherent law in matter, by which all bodies have a tendency to continue in the motion communicated to them, or remain in their natural state of rest. If a cannon ball be discharged from the mouth of a cannon, it requires an exertion of force to give it an impetus greater than would be required to continue its motion. If its progress be arrested whilst in motion, a shock will be experienced by the body which impedes it, the force of which shock will vary as the velocity of the ball. When this ball ceases to move without any *visible* impediment, it is not that its original impetus is exhausted or spent, (though the latter term is frequently used) but that it is gradually overcome by the particles of air which form a succession of points of resistance upon which its force is nearly destroyed, and it is then drawn down to the earth by the superior attraction of gravitation. If we could destroy the intermediate resistance of the air, the ball would continue in motion for ever, because nothing would intervene to destroy the primary impetus. This property of matter occasions a considerable destruction of power

in the steam engine. The motion of a massive beam, and its necessary appendages of machinery, a piston, connecting rod, parallel motion, and pump buckets, have to be reversed at each stroke of the engine, and that too when the speed is very great. The natural state of rest, or *vis inertiæ*, *i. e.* the force of inactivity, has to be overcome at the commencement of each stroke, and when a great velocity is acquired it is as suddenly checked to prepare for the returning one. This necessarily produces a great strain upon the machinery, which must be made proportionably more massive: and it requires likewise great skill in the construction of the engine house to prevent its being ultimately destroyed by the alternate push and pull which it experiences at each reversion of the beam. We have repeatedly noticed the best constructed engine houses shaken, and almost falling to pieces from this cause.

Various schemes have been proposed to remedy one of the evils of reciprocation. We mean the shock experienced by the reversion of the matter. It is not expected to prevent the loss of power sustained thereby; for that must remain as long as the law of which we have just spoken exists. Where a crank and fly wheel are used to obtain a rotatory motion, a *shock* is prevented by the velocity being gradually retarded, the crank having to perform a greater portion of its revolution with only the same surface of steam at the commencement and termination of each stroke of the piston: we explain our meaning by reference to the marginal diagram.



a b is the crank of a steam engine, of which the semi-circle, *d*, *c*, *a*, *c*, *f*, represents the motion communicated by one stroke of the piston; when, therefore, the crank in its present position is moved from *a* to *c*, the piston is at its greatest speed, and travels nearly at the same velocity as the point *a* of the crank. But when moving from *c* to *d*, an equal piston of a revolution, the piston only moves a distance equal to *g d*, in the same space of time, as it had previously moved a distance equal to *b g*, almost double of *d g*. Hence it appears that the crank, by gradually decreasing the speed, is admirably adapted for preventing the violent shock which would otherwise be experienced by the piston striking the top and bottom of the cylinder, and by changing the motion of the beam too suddenly, but it does nothing towards reducing the power lost by reciprocation. In pumping engines, where a fly wheel and crank are not used, other means are adopted to check the force of the piston, or guard against the shock of suddenly changing the motion of the beam. In the coal districts the usual way is to shut off the steam when about two thirds of a stroke has been performed; the expansive force of that already in the cylinder, together with the impetus of the piston sufficing to barely carry it to the termination without violence. In such engines springs are sometimes fixed above and below the beam, so as to check its progress should the steam possess

more force than may be expected. "It once happened," says Mr. Farey, "that the valve of the pump bucket breaking, the engine suddenly lost its load or resistance, which occasioned the piston to descend and strike on the spring beams for two or three successive strokes with such violence as to break one of the beams, and at last the piston striking the bottom of the cylinder, the *momentum of the beam* forced down upon the rod so violently as to bend the great piston rod quite crooked. To prevent similar accidents, a smaller steam pipe was added to the side of the vertical steam pipe communicating with the passage into the bottom of the cylinder. This pipe is kept closed by a valve; but if the engine descends so low as to strike on the spring beam, a catch pin on the beam strikes a small lever, and by a wire of communication opens the valve and lets the steam into the lower part of the cylinder beneath the piston and thus destroys the vacuum, so as to prevent the further descent of the piston."

This addition, it will be understood, applied only to the single acting engine, but it serves to shew that the objections we have given arising from momentum are not merely theoretical.

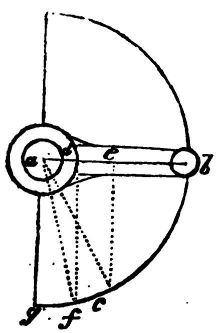
The beautiful addition of the crank to the steam engine, although the means of extending its utility tenfold has been the subject of much objection. Engineers and others possessing considerable claims to the character of scientific men, have not unfrequently maintained that there is a considerable loss of power by the change in the length of the lever as the crank revolves. We shall endeavour to show the error into which such persons have fallen.

The principle of the lever is so well known, that it is scarcely necessary to explain it: lest, however, it should not present itself to all our readers, we shall give a short description. "In all levers the universal property is, that the effect of either the weight or the power, to turn the lever about the fulcrum, is directly as its intensity and its distance from the prop; whence it is deduced, that if parallel forces acting perpendicularly upon a straight lever keep it in equilibrio, they will be to each other reciprocally, as the distances from the fulcrum upon which they act." * Thus, supposing a bar of four feet in length be fixed upon a fulcrum exactly in the middle, and an ounce weight be suspended at each end, the two ends will be in equilibrio, because the force of gravitation is equal, neither possessing it in a greater degree; but if the fulcrum be shifted and placed three feet from one end, then it will require three ounces at the shorter end to balance one ounce at the other. If motion be given to the shorter end whilst the fulcrum remains the same, the end of the longer lever will traverse three times the space of the shorter.

The crank of a steam engine is a lever whose fulcrum is at *a*. It is the nature of the crank that its power or leverage varies with its position. Let *a b* represent the crank, the point *b* is moved by the connecting rod, and revolves round the centre *a*. Supposing the resistance be equal to 100 lbs. or that 100 lbs. have to be raised 3.1416 feet for every revolution of the crank: it is evident if a force or weight

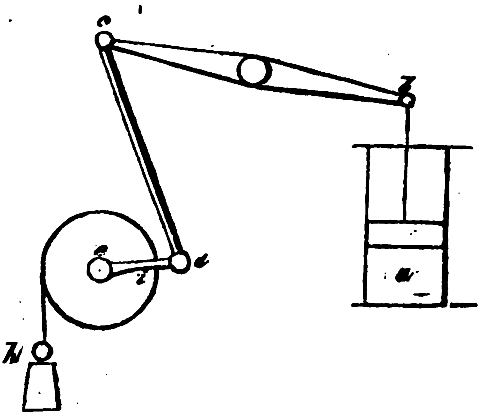
* Good and Gregory.

exceeding 100lbs. be applied at *b*, whilst the crank is horizontal, it will be sufficient to raise the weight. But when the point *b* has descended



to *c*, the length of the lever being described by its sine, the vertical line, *e c*, drawn through *a b*, shews *c a* to be the length of the lever, which is only one half of *b a*. It would, therefore, require a weight double of the former to continue the motion. And if the crank descend to *f*, the vertical line, *d f*, shews *d a* to be the length of the lever, and to be only one fourth of what it was when horizontal. When it reaches *g* no power on earth applied through the medium of the connecting rod, would further continue the motion.

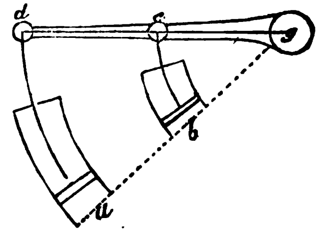
To equalise this irregularity, and in some degree to compensate this great variation, the cylinder is of such dimensions as to give out a considerably greater power when the crank is horizontal than is then necessary. This extra power is employed to give motion to the fly wheel, which is of sufficient dimensions to retain the impetus until it is past the point *d*, when the steam begins to act with effect upon the lower side of the piston.



Let *a* represent a cylinder, the length of the stroke of the piston being two feet. *d e* is the crank, the length of which is one foot; *b c*, the beam, the fulcrum of which is exactly in the middle. If the piston be put in motion the extreme end of the crank will describe a semi-circle of 3.1416 feet. Now let us suppose that a drum be fixed upon the axle *e*, whose circumference is four feet, equal to one ascending and one descending stroke of the piston. If a weight be suspended by a rope to this drum, as at *h*; the power of the engine

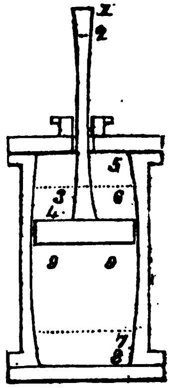
at that point will exceed the power necessary to raise the weight as much as *d e* exceeds *i e*. This extra power is communicated to the fly wheel, which faithfully gives it out when required. When the crank has descended so as to decrease the length of the lever, that it is shorter than *i e*, then a portion of the extra power in the fly wheel is destroyed in aiding the decreased leverage of the crank. And although the power gradually decreases, yet the speed of the piston gradually decreases also, so that if the power of the crank be only one half in a certain position, yet the quantity of steam used is only one half, and thus the effect of no part of the steam is wasted, the effect being in every point equal to the steam expended. It is true that if we could have applied the power at a point equidistant from the centre in every part of the revolution, we should have obtained much greater leverage, but then the expenditure of the steam would have been proportionably greater.

We will further explain this theory by referring to another diagram. *g d* represents a lever like the crank: *g* being the axle. *a b* are two vessels fitted with pistons, and in every respect resembling cylinders, excepting that they are curved so as to describe portions of circles formed from the point *g*. We will suppose that the piston in *a* acts upon the extremity of the crank, and that in *b*, at half the distance from the centre. The vessels are of the same area, so that if steam were introduced from a boiler, it would press with equal force upon each piston, and consequently the rods would each press with an equal force upon the points, *e d*. Now it would be maintained that, because at *e* there is only half the leverage, therefore half the effect of the steam in *b* is lost; but it will be found, that if that lever, *g d*, be moved any given distance round its centre, that the piston, *b*, only moves half the distance of the piston, *a*; and consequently, the areas being equal, and the distance but one half, only half the steam is expended. Hence it is clear, that the consumption of the steam in every point of the lever is only equal to the effect produced.



There are minor objections against Watt's engine which, nevertheless, should be noticed. One is the waste of steam at the reversion of the motion of the piston. First, from the pipes between the valve and the cylinder. In filling the cylinder these must be filled, and in discharging, these must likewise be emptied; so that they are filled and emptied at each change of the motion. But in the cylinder every particle of the steam produces an effect: whilst here the steam used produces no effect, and is therefore wasted. Secondly, from the changing of the valves themselves at the improper time. It may indeed be said, there is no proper time to change the valves, because there is no time at which they can be changed without disadvantage by loss of steam; and the difficulty of determining the precise time frequently occasions their being changed at such a time as to waste more steam than is unavoidable. The necessary waste arises from the change of the valves being

a work of time, whilst the reversion of the stroke is instantaneous: therefore, either the change of valves begins too soon, and admits steam into the vacuum before the stroke is completed, or ends too late, and admits steam into that part of the cylinder when a vacuum is forming, thereby preventing its formation; or otherwise it is attended with both these disadvantages. The improvements in the valves, we are sorry to say, have but increased this difficulty, and which we shall notice in their proper place.

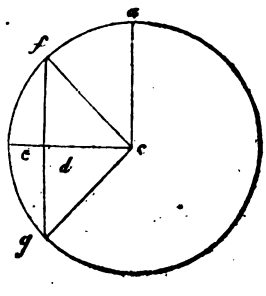


Another disadvantage is the unequal form into which the cylinder and piston rod become worn after having been some years in use. This arises from the varied speed at which they travel, and to their not passing over all parts of the surface. We have seen a piston rod in use full as much out of form as that in the drawing, and cylinders nearly so. The form of the piston rod arises from the parts 1, 2, and 3, 4, being only partially drawn through the stuffing box, consequently less *rubbed* than the middle, which is drawn through at each stroke. The decreased diameter in the middle of the rod arises from the speed being greater there than at other parts, (the cause of which we have explained) and creates in consequence a greater wear.

The irregular wear of the cylinder is produced in the same manner. The piston is not drawn through, but merely comes in contact, or is partially moved through 5, 6, and 7, 8, whilst it rapidly passes the middle, and therefore, in that part, it is more worn than at any other.

The last inconvenience we shall notice, though it is by no means the least, is, that the fly wheel is the constant and indispensable accompaniment of the crank. This will appear evident from what we have already stated.

Independent of extra cost, extra friction, and extra room, it becomes necessary to have two engines in steam boats, to obtain any thing like a regular motion, and even this is far from regular. In steam boats the two cranks are fixed upon the same axle as that on which the paddles are placed. By this contrivance, when the crank of one engine is passing the centre and has no power, the other is at its greatest power, and thus aiding each other, something like an equality is preserved: but this is irregular, as a variation still takes place in the mean length of the two levers. *a c*, and *c b*, represent two cranks, the axle of which is *c*. *a c* is now passing the centre, and therefore has no power, whilst the other, *c b*, is at its greatest power. The mean length of the lever, therefore, is at *d*, or one half of *c b*; but when the two cranks have made one eighth of a revolution, as to *c f*, and *c g*, then the line, *f g*, shews the mean power to be at *e*; having varied from *c d* to *c e*.—



This irregularity being unaided by a fly wheel may probably account for the vibration which we feel in many steam boats, and which appears to proceed from some other cause than the reciprocation of the parts. It should be observed that the impetus of the boat makes the paddles act as a kind of fly wheel, because if they were suddenly disengaged from the machinery they would continue to revolve of themselves so long as the velocity of the stream was less than the velocity of the boat, because then the stream acts like the current for an undershot wheel. So long as the vanes continued to be driven against the water, so long would the motion of the wheels be continued in the same direction as that given by the machinery; therefore we say, they are fly wheels of a peculiar kind; but still as the speed would immediately decrease as they were disengaged from the machinery, from the yielding nature of the medium through which they pass, so also would they vary in velocity as the mean power of the crank increases or diminishes.

It will be readily conceived that these disadvantages must have exercised the talent of many ingenious men. All have agreed that the remedy might be found in a circular or rotatory motion, obtained from the steam itself, without the aid of the beam, crank, or piston rod. That if this could be effectually done, it would do away with almost every defect of which we have spoken. Reciprocation would be removed, as well as irregularity in the power of the lever; and as for friction, that of the beam and appendages would, at all events, be destroyed: but it has been found that, hitherto, notwithstanding the advantages attendant on this kind of engine, inconveniences and difficulties have been found, peculiar to each varied form, or common to all that have precluded its adoption in preference to the reciprocating engine. The defect in many of them has been excessive friction, and, in nearly all, the difficulty of maintaining the packing steam tight: this is as much as we can say as to the general objection. We shall direct the attention of the reader to several of the best rotatory engines, and endeavour separately to shew the causes of failure.

The shrewd and investigating mind of Watt seems to have directed itself in the very outset of his career, to the desirableness of such an engine: for we find in his patent of 1769, (the specification of which we have examined,) that a rotative engine is one of the inventions included therein, and seems to claim precedence in his judgment (if we may judge by the order in which they stand) to the use of hemp and oil in packing, instead of water as in the old engines.

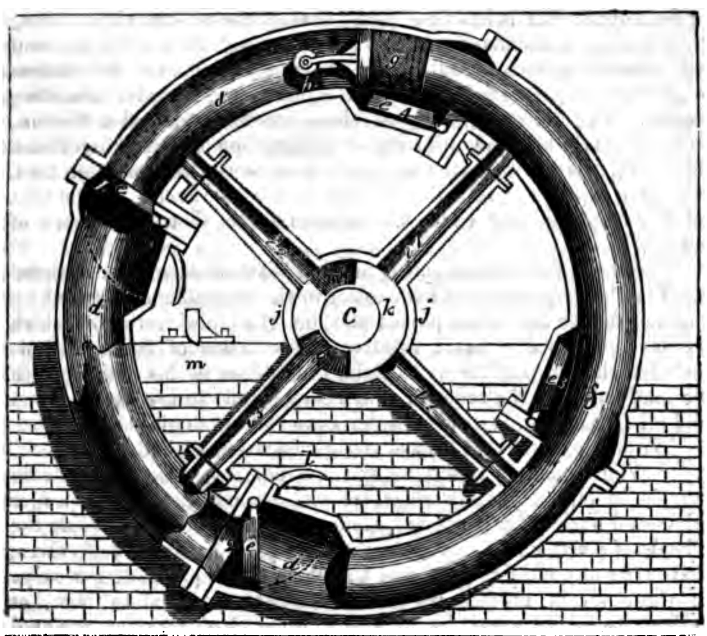
We will extract that part of the specification verbatim.—

"Where motions round an axis are required, I make the steam vessels in form of hollow rings, or circular channels, with proper inlets and outlets for the steam, mounted on horizontal axles like the wheels of a water mill. Within them are placed a number of valves, that suffer any body to go round the channel in one direction only: in these steam vessels are placed weights, so fitted to them, as entirely to fill up a part or portion of their channels, yet rendered capable of moving freely in them, by the means hereinafter mentioned

or specified. When the steam is admitted in these engines, between these weights and the valves, it acts equally on both, so as to raise the weight to one side of the wheel, and by the reaction on the valves successively, to give a circular motion to the wheel; the valves opening in the direction in which the weights are pressed, but not on the contrary. As the steam vessel moves round, it is supplied with steam from the boiler, and that which has performed its office may either be discharged by means of condensers, or into the open air."

There is a great deal of confusion and ambiguity in this part of the specification, as, indeed, there is throughout, so much so, that we are surprised that the patent was ever sustained, since it is required that all specifications should be so clear, "that a person of moderate capacity, having a little knowledge of the science which led to the invention, can immediately see the method pointed out, and easily apprehend the purport for which the subject was invented, *without study*, without any invention of his own, and without experiments."* No drawings are given of any one of the six inventions included in this patent, and the reader may judge by this specimen whether any one can comprehend it without study. After much study we have been able to come at the meaning of the patentee, by supplying the form of the valves, and indeed, most of the principal parts, and in that form we submit it to our readers as

THE FIRST ROTATORY ENGINE.



* Godson on Patents, p. 109.

In explaining its principle we shall repeat the words of the specification, making such alterations in the language as may make it understood.

"Where motions round an axis are required, I make the steam vessels in the form of hollow rings, or circular channels, with proper inlets and outlets for the steam" (as at *a* and *b*), "mounted on horizontal axles" (*c*), "like the wheels of a water mill. Within the *circular channel*" (*d d d*) "is placed a number of valves" (*e e e e*) "that suffer any body to go round the channel in one direction only: in *each steam vessel* is placed a weight" (*f*), "so fitted to it" (by packing at *g*) 'as entirely to fill up a part or portion of its channel; yet rendered capable of moving freely in it by means hereinafter mentioned. When the steam is admitted between the *weight* and valves, it acts equally on both, so as to raise the weight to one side of the wheel; and by the re-action on the valves successively, to give a circular motion to the wheel, the valves opening in the direction in which the weights are pressed. As the steam vessel moves round, it is supplied with steam from the boiler, and that which has performed its office may either be discharged, by means of condensers, or into the open air."

Now that we have made the language a little clearer, we shall proceed to describe such a machine as we imagine the inventor had in his mind; informing our readers that the hollow arms, form of the valves, manner of admitting the steam and allowing it to escape, are added as the best means we can devise to answer the proposed end; but we are not aware how they were really formed, whether at the time the specification was drawn up, the inventor had any decisive plans in view; or, that he (like too many patentees) trusted to the resources of his own mind to supply them when he proceeded on the experiment.

d d d is the circular channel, bolted together in segments, in which the weight, made of cast-iron or lead, *f*, can move freely. The weight is packed with hemp at *g*, so as at that part to fit so tight in the channel, as to prevent the steam from escaping past it. *i i i i* are four hollow arms, communicating with the hollow ring, and with a cylinder or bush *j j*, into which is fitted a circular plate of metal *k*, having two cavities *a b*, in the situation shown in the drawing. *k* is covered with another plate to which it is accurately fitted, to this outer plate is attached the eduction pipe which communicates with *a*, and the induction pipe, which communicates with *b*; the plate *k*, and its covering, remain stationary, whilst the wheel revolves, and the open end of the arms *i i i i*, successively pass over the open spaces *a b*, and admit the steam or suffer it to escape, as we shall now explain.

The steam being admitted from the boiler rushes through the arm *i* 3, into the channel, and, shutting the valve *e* 1, or finding it already shut, forces up the weight *f f f* into one side of the wheel, (as shown in the drawing); this causes that side to preponderate, and in endeavouring to regain its former position makes the wheel to revolve. But, in the mean time, a supply of steam is kept up from the boiler, which preserves the weight in its present position, driving the wheel

round in the opposite direction, whilst the valve *e* 2, having passed the situation it is now in, is shut by the lever *l*, striking the tappet *m*, and receives the force of the steam, previously upon *e i*. When the wheel has revolved a little further, the arm *i* 3 communicates with the eduction passage, and allows the steam to escape which was between the valves *e* 1 and *e* 2. Immediately after, the valve *e* 1 strikes against the friction roller *h*, and is by it forced into the recess, assuming the position of *e* 4. At the same time the valve *e* 3 has got clear from the weight, and falls by its own gravity into the position of *e* 2, after which it is shut by the tappet *m*, in the way already explained. Thus the valves successively receive the action of the steam, and the weight being preserved in its elevated position the wheel continues to revolve.

Such was the plan designed as the first rotatory engine. It is because it *was* the first, and because it was the invention of Watt, that we place it here. In itself it possesses few claims to our attention. If such a machine could ever be made, (which is doubtful) the excessive friction of the weight moving in the channel would exceed that of the common engine tenfold. But the worst fault would be, that the packing could not be preserved steam tight for any length of time: for hempen packing it is well known cannot pass over in its course any cavity, or irregularity of surface, without being soon torn out, and rendered incapable of performing its office. It would also be required that the interior of the channel should be accurately turned, which might be effected in small engines by turning a section of the wheel at once, (such as our drawing represents) and afterwards bolting two of such sections together; but in large diameters, such as would be absolutely necessary for large powers, the vibration would render their being turned an absolute impossibility.

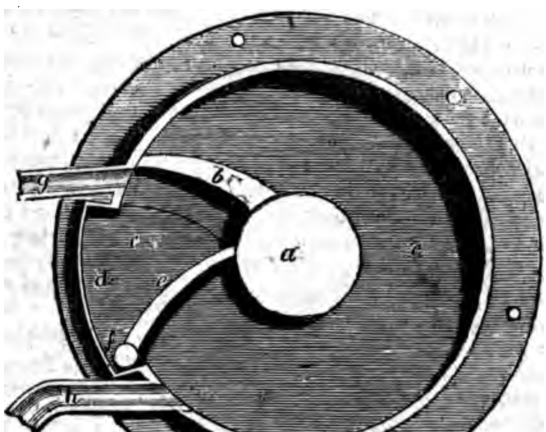
We cannot learn whether Watt ever proceeded on the experiment. He himself states that—" a steam wheel, moved by force of steam acting in a circular channel, against a valve on one side, and against a column of mercury, or other fluid metal, on the other side, was executed at Soho, upon a scale of six feet, and tried repeatedly, but was given up as several objections were found against it." From this we may conclude that the patented machine had probably been tried and abandoned, on the ground of excessive friction.

We have likewise some information on the subject of Mr. Watt's experiments on rotative engines, by Mr. Farey, (in his article Steam Engine, which is to be found in Rees's Cyclopedia,) who says, " One of his first trials was uncommonly ingenious; it consisted of a drum turning air-tight within another, *with cavities so disposed,* that there *was a constant and great pressure urging it in one direction;* but no packing of the common kind could preserve it air-tight with sufficient freedom of motion. He succeeded by immersing it in mercury, or in an amalgam, which remained fluid at the heat of boiling water, but the continual action of the heat and steam, together with the friction, soon oxydated the fluid and rendered it useless. He then tried Parent or Barker's Mill, enclosing the arms in a metal drum, which was immersed in cold water. The steam rushed rapidly along the pipe

which was the axis, and it was hoped that a great reaction would have been exerted at the end of the arms, but it was almost nothing. It was then tried in a drum kept boiling hot, but the impulse was very small in comparison with the expense of the steam."

The former part of this extract is about as obscure as the specification which we have just noticed. We should certainly have expected from a man of Mr. Farey's experience a somewhat clearer account of any experiment than that with which we are furnished; for to say there "was a machine with cavities so disposed that there was a constant and great pressure urging it in one direction," conveys no further idea than that a motion was *somehow* obtained, but how, it is utterly impossible to know. The amount of this extract is, that Mr. Watt tried a great number of experiments in order to obtain a rotatory engine, and that in these experiments he failed. The information we gather from Mr. Farey might have been said in as few words.

The second patent of 1782 (for there were two patents of that year, one in February and the other in July) describes a rotatory, and semi-rotatory, or reciprocating rotatory engine. To the rotatory engine we shall first direct the attention of the reader.



c c is a cylinder of any given dimensions, say a foot deep, and three feet diameter. *a* is an axle, passing through stuffing boxes in each lid or end of the cylinder. *b* is the piston packed at the ends which rubs against the cylinder, and at the sides which rub against the lids, which are previously turned; the form of this piston, therefore, is square, packed on three sides, and fixed to the axle *a* on the fourth. *e* is a valve or flap, which turns upon a joint or pivot *f*: the concave side is a segment of a circle of the same radius with the cylinder.

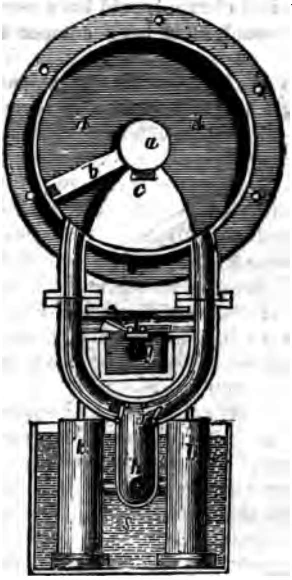
It extends the whole length of the cylinder, is packed on its sides; and when shut back into the cavity *d*, becomes, as it were, a part of the cylinder: completing the circle, which is imperfect when the valve is in its present situation. *g* is the pipe for admitting the steam from the boiler, and *h* the pipe for allowing it to escape into the condenser.

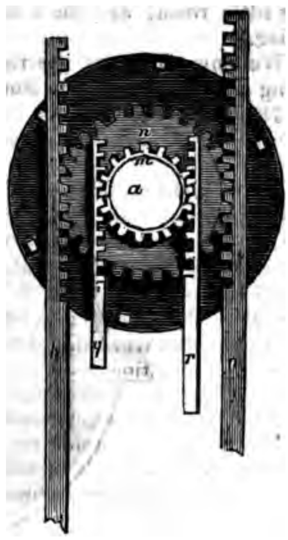
Steam being admitted from the boiler through *g* presses equally upon *e* and *b*, but *e* being stopped against the axle, the piston *b* recedes from the pressure, and turns the axle *a* and a heavy fly wheel round with it. The piston continues in motion until it comes in contact with the lower side of the valve *e*; where it would stop but for the impetus of the fly-wheel, which urges it forward, and it strikes the valve *e* into the recess *d*, and moves round until it passes *g*, when the valve, either by a lever or by its own gravity, resumes its present situation, and the piston receives the action of the steam as before.

This plan, we are informed, was never carried into execution, and we must, therefore, as in other instances, endeavour to trace the objections from subsequent experience, but there have been so many schemes closely resembling this, that these are easily ascertained. The principal objection appears to be that it would be liable to derangement, as the violence with which the valve would be alternately driven into the recess, and upon the axle, would speedily shake the machine to pieces; besides which, it would be impossible for the packing used in the reciprocating engine to pass over the pipes *h g*, without being torn up and rendered useless. A great waste of steam must likewise take place whilst the piston is passing over the surface of the valve: for at that time the steam pipe *g* has a free communication with the eduction pipe *h*; and every one acquainted with the subtle nature of steam must be aware that as much steam would thereby escape, without producing *any* effect, as would have been sufficient to work an engine free from that defect. This last objection might be obviated by shutting off the steam during that part of the revolution; but the specification proposes no such method, and we are not authorized to make any gratuitous addition.

The semi-rotative engine next comes under our notice. *d d* is the interior of the cylinder, similar to the last. It is likewise fitted with a piston *b*, packed in the same manner. *c* is a projection of metal extending from the circumference to the axle *a*. Packing is introduced between this projection and the axle, so as to prevent the steam from escaping between them. *e f* are two valves which admit steam from the steam pipe *g* into the cylinder on each side of *c* alternately. *o f* are two valves for changing the direction of the steam: *i j* are two valves acting in conjunction with *e f*, so as to open or shut off a communication with the condensers *l k* through the pipe *h* at the proper time. Levers are attached to the rods by which these valves are worked, from tappets on the pump rods *r q*.

Steam, as admitted from the boiler through the pipe *g* into the steam chest, and finding the valve *f* open, rushes up the pipe, and so into the cylinder between the piston and stop *c*. The piston, receding from the pressure, drives the air in the cylinder through the





other pipe, and down through the valve *j*, into the condenser, whence it escapes by the pump *l*. It continues revolving until it comes in contact with the other side of *c*, when it is stopped; but previous to this the valves *f* and *j* have been shut by their respective levers, whilst *c* and *i* have been opened. The steam has now access through *e* to the other side of the piston, and turns it in the contrary direction; the steam which last performed its office escaping down through *i* to the condenser. The first operation is then repeated, reversing the motion of the piston as soon as, or before it comes in contact with the other side of *e*. *n m* are two toothed wheels attached to the axle *a*, which work (as shewn) by racks, the pump rods *o p*, and the smaller pump rods *q r*. The former *o p*, are supposed to draw water from a mine, but the smaller ones only work the condensing pumps *k l*.

This is, really, a clever machine. It was never, we understand, carried into execution, but why, we can scarcely tell. It would hardly be an objection that the piston would strike against the stop *c* and thereby shake itself to pieces: for here, as an equable motion is not required like a rotatory engine, the speed might (as in all pumping engines which were liable to the same objection) be gradually retarded, so that the impetus would be destroyed before it came in contact with the stop. Perhaps the most solid objection would be that of the packing requiring more care than a common workman, such as generally attends to steam engines, would be able or willing to bestow; but if this were found a conquerable objection, we can scarcely conceive a reason why it should not have had a fair trial. It

would have been extremely portable and cheap, would have occupied very little room, and the friction would have been comparatively trifling.

We now close our descriptions of Mr. Watt's inventions, by giving a short account of a Rotatory Engine, included in his patent of 1784.

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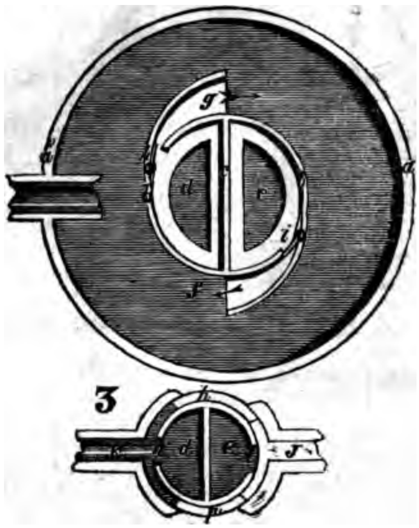

Fig. 1 is a ground plan, and *fig.* 2 a section. *a a* is an external cylinder, or reservoir, filled with heated water, quicksilver, or an amalgam (which would become fluid at the boiling point). *b b* is an interior cylinder in the middle of *a a*, and turning upon a pivot *o*. A partition *c*, reaches from top to bottom, dividing the vessel into two equal parts. *d e* are two valves, allowing the liquid to ascend and fill the interior of *b b*, but preventing its egress in that direction. *f g* are two tubes, or apertures, for guiding the escape of the liquid in the direction of the arrow. *j* is the pipe for the admission, and *k* for the exit, of the steam. The steam being introduced from the boiler through *j* enters the cavity *l*, and passes on the surface of the water, driving open the valve *i*, (*fig.*1) and issuing through *g*, in the direction of the arrow, thus pressing upon the body of the liquid in the reservoir, and producing a re-action, which drives the internal vessel round. When it has performed nearly half a revolution the cavity *n* comes under the steam passage. This will be understood better by *fig.* 3 : *p p* is a hoop encircling the upper part, or neck, of the vessel *b b*; *l* is a hole in the side of the vessel communicating with one side of the vessel, and *n* a similar hole communicating with the other. It will be seen that, at present, the hole *l* communicates with *j*, and the hole *n* with *k*, but, by turning the vessel half way

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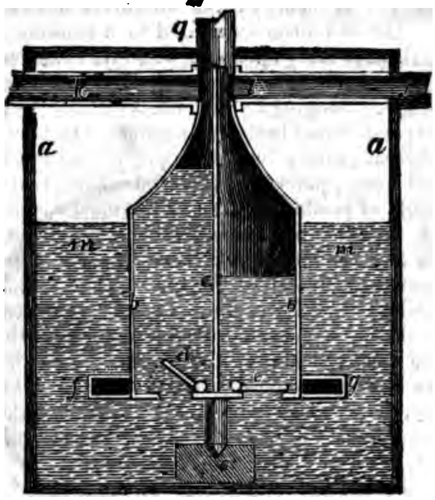


round, their situations will be reversed; *l* communicating with *k*, and *j* with *n*, so that each side is successively exposed to the action of the steam, and to the condenser. By this means, therefore, the hole *n* is next in communication with the steam pipe *j*, and the valve *d* being shut by the steam pressing on the surface of the liquid; the valve *i* is opened by the same means, so that the liquid is forced with violence through *f*, in the same manner as it was previously forced through *g*. Whilst this operation is going on, a vacuum is formed in the first vessel (by *l* communicating with the condenser) so that it becomes charged and ready in its turn to receive the action of the steam. When it does, the first operation is repeated, and a rotatory motion is kept up by the alternate action of the liquid driving through the cavities *f g* in nearly the same manner as the motion is produced in the well-known machine commonly called Barker's Mill, differing only thus :—that the water from the latter acts against the air, whilst this acts upon the fluid in which this is immersed. The motion is carried through the top of the reservoir *a* to a stuffing box *q* (not shown), and attached to the machinery.

It appears this machine was tried, and found to have little or no power; which, of course, was the reason of its abandonment. The cause of its trifling effect arises from the force of the escaping liquid acting upon a medium, which affords no solid resistance, and is, therefore, incapable of producing any powerful re-action in the machine.

We close our detail of the inventions of this truly great man, by remarking, that there have been few men who have contributed so much to the promotion of commerce and manufacture; yet, whilst we admit him to have been capable of producing the most wonderful

effect of the mind, there are some of the inventions which have come under our notice that many of the obscurest mechanicians would blush to own. He has been compared to a walking encyclopædia, and the comparison is truly apropos, when we consider that an encyclopædia is the reservoir of the most worthless, as well as the most useful, knowledge. Judging by the effects which his inventions have had upon society, we cannot hesitate a moment as to determining that he is deserving of great praise; but judging by those inventions which he put on record in his many patents, we feel astonished that the same mind should be capable of producing ideas of the most useful and the most worthless kind. Incapable of discriminating, he seems to have no sooner formed an idea than he has made it the subject of a patent, so that we found almost three out of four of the schemes which are included in his specifications have never been carried into execution.

We have already expressed our opinion respecting Mr. Watt's eager desire to secure to himself the benefits of any idea that entered his mind, even in the most unsubstantial form. In this opinion we are not solitary, in proof of which, we make the following extracts from a letter addressed to Sir J. Eyre, then Lord Chief Justice of the Common Pleas, by Mr. J. Bramah, dated 1797.

Speaking of Mr. Watt's first specification, on which we have already remarked, he says, "In considering the part arranged *first* in this specification, I cannot observe the words there used create in the mind of the reader any new idea respecting the construction, proportion, or office, of that part of an engine properly called the steam cylinder. The enquirer is left wholly uninformed, whether the intended cylinder, or steam vessel, is to be left open at top, and shut at bottom, or shut at top, and open at bottom, or whether both its ends are to be alike shut; nor is he directed in what manner the steam is to be admitted into the cylinder, or in what manner discharged: there being no mention how, and in what part of the cylinder, the necessary inlets and outlets are to be contrived, notwithstanding the essence of every engine depends thereon. There is likewise no mention made of the form and action of the piston, or the method of connecting it with the external and working parts of the machine, or whether the expansive force of the steam is exerted on the upper or under side of the said piston; or even whether there is a piston employed at all."

"This part of the specification appears calculated to mislead and perplex; and I am fully persuaded, were these imperfect directions given to any workman, even of the most eminent knowledge in the art of building engines, they would tend directly to frustrate every regular step necessary to be taken in the progress of such a work."

"Had there been a shadow of a guide introduced into this mysterious composition, an ingenious mind might have acccidentally stumbled on the inventor's mark; but it is so much the contrary, that every adventurer is constrained to explore a way for himself, and to wrap his cylinder in any warm covering his powers of judgment may suggest: and it is my firm opinion, that were engine builders in general left to puzzle out this single circumstance, ninety-nine

out of every hundred would attempt a different method of accomplishing the inventor's intention; and I am likewise as fully convinced, that a like proportion would finally miss their aim, in spite of repeated efforts."

"The first thing which attracted my attention when inspecting an engine built by Mr. Watt, was the steam cylinder, which I observed shut at both ends, contrary to that of Newcomen, which is always open at the upper end, whereby the atmosphere acts upon the upper surface of the piston, both in its ascent and descent."

"A slight pause on this circumstance soon presented to my view a total contradiction to the article in Mr. Watt's specification, denominated *fourthly*, where he asserts that 'he intends in many cases 'to employ the expansive force of steam to press on the pistons, or 'whatever may be used instead of them, *in the same manner as the 'pressure of the atmosphere is now employed in common fire engines.*'"

"On reading this paragraph, every person acquainted with Newcomen will naturally ask,—How can the expansive force of steam be applied to press down the piston in the manner it is now performed by the atmosphere, which requires the top of the cylinder to be kept open? For, suppose steam to be poured on to the top of it instead of air, where is there any footing or abutment for the re-action of this expansive element? I clearly perceive, says the enquirer, that the air performs this office by its gravitating power, which requires no butment. But how can any expansive force be employed without it; since it is a law of nature that no force of this kind can be exerted without being first prevented from expanding on the contrary; or at any rate, without having a resistance in all directions, equal at least to the force of action required?

"These reflections, I conceive, would induce a conclusion, that the man who proposed such a thing must be either a fool or a madman. But to return—

"On considering the strange difference I saw in this machine from that of Newcomen, I concluded in my own mind the following to be the real invention of Mr. Watt in the cylinder part of the engine. First,—He has completely inverted the order of Newcomen, by turning the cylinder upside down. Secondly,—By making the proper inlets and outlets for the steam, at the upper instead of the lower end of the cylinder. Thirdly,—The valves used in these inlets and outlets, for the purpose of admitting and shutting off the steam, and for retaining it in the cylinder and discharging it; the manner of giving motion to them from without, are very peculiarly and curiously contrived, and totally different from any article ever applied in Newcomen's Engines for the same purposes; and these valves, &c. I observe, are made always of brass, or a mixture of copper and brass; and I cannot see of what other metal such very essential parts could be made; as iron would soon rust, and in a few weeks lose the perfection requisite to keep them air and steam tight. Fourthly,—I cast my eye on a single part of the engine, and which part not being properly accomplished, would render finally abortive all the efforts it is possible to make in giving motion and power to the machine."

"This, my lord, is the mean adopted for giving motion to the external mechanism of the engine, by connecting it with the piston, which is here close shut up in the internal part of the cylinder; and as I have already observed, the cylinder is placed with its bottom upwards, compared with Newcomen's, this connection between the internal and external motion must of necessity be communicated through the bottom, which now becomes the top of the cylinder. As the entire effect of the engine depends on ascertaining a method of doing this completely, and seeming to form a most material part of the whole invention, I will be more particular in describing it to your lordship, and begin by stating how this was performed by Newcomen.

"In all Newcomen's engines, where the top of the cylinder was entirely open, the piston was connected with the working beam by a single or double iron chain; in most cases double at the upper end next the beam, and the lower end commonly formed a junction with the piston by an intermediate strong bar of iron, in some cases a strong rod of wood shod with iron. By this means the force the piston received from the pressure of the atmosphere was communicated to the beam above, and that in as rough a manner as the workmen pleased to make it; the smoothness and truth of workmanship being unnecessary in this case.

"But, only behold, my lord, the difference required in Watt's engines in this one particular!

"The above two motions are to be connected by means of a rod or other contrivances, (for a chain, &c. will not answer here) which must not only pass through an aperture in the cap or top of the cylinder, steam and air-tight, but this aperture is required to be kept thus close during every stroke the engine makes.

"This cannot fail of striking your lordship in a serious point of view; and, from what has been said, it must involve a conclusion in your mind, that this part is one grand essential, if not the most so, of any in the machine; as the smallest imperfection here will admit the air when the vacuum is made, and thereby completely stop the engine.

"Having thus prepared your lordship, I will now describe that which Mr. Watt should have done, *i. e.* the manner in which the internal piston is connected with the working beam without.

"This is by an iron rod of a sufficient diameter, turned and otherwise worked so as to be perfectly smooth and parallel from one end to the other, and of a length sufficient to allow the full stroke of the piston within; and I think it necessary to remark, that if in this rod there should be the smallest rag or flaw, it is totally unfit for its purpose; for reasons that will appear hereafter. And I am certain, from my own knowledge, that Mr. Watt in his first outset on this business, found more difficulty in procuring these rods in all respects perfect, than he would have done in constructing all the parts of Newcomen's engine; although this article, like the rest, is not mentioned in his specification.

"Fifthly,—I shall proceed to explain to your lordship a circum-

stance in this part of the engine, in my opinion, as material and of equal consequence with the preceding, or any other article in the machine. This is the method of rendering the aperture, through which the piston rod passes, constantly air and steam tight; notwithstanding the said rod in many engines slides through this aperture no less than three hundred and twenty feet per minute during the time they work.

"This junction or aperture is a very ingenious contrivance, and is called a stuffing box; it is a part formed in the centre of the cap or top of the cylinder; and is a kind of cylindrical box, of about six or eight inches deep, made of iron. The upper part of this box is considerably wider than the diameter of the piston rod above-mentioned, and the bottom or lower part next the inside of the cylinder is made exactly to fit the said rod. From this part, for a small distance upwards, the box is turned in a conical form, so as to make a chamber exactly in the shape of a snuff mull; at the top of this conical part is turned a rebate or seat, into which is fitted a brass or iron ring, the extreme circle of which exactly fits the cylindrical part above the conical part described. This conical chamber is then filled with hemp or junk, so as to surround the piston rod on all sides; and being secured down by the brass or iron ring above-mentioned, causes the rod to slide steam and air-tight. But the quantity of rub which is constantly on this part, and the nice perfection required, soon discovered the want of some farther help; and something similar to the means just treated on for keeping the piston tight, suggested itself at an early period of Mr. Watt's experiments, which is effected as follows.—

"In the cylindrical part of the box is turned another rebate, about an inch more or less above the ring which secures the lower packing; and into this rebate is also fitted a ring as before, which causes a space between it and the lower ring. Then above the upper ring is turned another cylindrical part like the former, having, of necessity, a greater diameter. This conical chamber is likewise packed with hemp, junk, &c. and this packing also fastened down by means of a ring, rather more in a plug form, and so contrived as to admit of being screwed down at pleasure, for the purpose of compressing the packing as worn away by the friction of the rod. The stuffing box completed, a small tube is inserted by one of its ends at the side of the said box, so as to communicate with the open space comprehended between the rings. The contrary end of this tube is joined to the steam pipe or boiler, where the steam is always active; and by this means a constant supply of steam is thrown into the space aforesaid, which steam preserves the rod air-tight; being kept as strong or stronger than the pressure of the outward air. Thus the steam here does the office of water, &c. on the piston of the engine when the packing becomes rather insufficient.

"I think, my lord, I need not say more on this point, to prove the necessity of a full and clear specification; and the practicability of giving one had there been a willing mind.

"Sixthly—I observe the lower end of the steam cylinder to be

also closed; and that the steam has alternate communication with the cylinder above and below the piston, just contrary to that of Newcomen.

"To detail the true nature of all this would be tiresome to your lordship; and as Mr. Watt has not done it, I shall decline doing it for him; though certainly well able.

"Seventhly—I come to what is called condensers. On this part of the subject I am almost puzzled what to say. From the specification I can say nothing; from the engines, they have been made in all forms; and that, by changing about and mixing the knowledge of every person in his way for twenty years at least, Mr. Watt has been taught what is the real fact, and what they confessed to be so on the late trial, namely, that no condensers are necessary but that which Newcomen calls the eduction pipe, and in which the condensation is performed by a jet of cold water, answers the same purpose equally well.

"Then it appears, my lord, that twenty years exercise of the superior abilities of Mr. Watt, with the help of all he could gain from the knowledge and practice of other men, and the assistance he received through the space of six years more from Professor Robinson, Dr. Roebuck, Mr. Cummings, and, no doubt, many others, eminent in the theory and practice of the arts, was only to prove what I said before they acknowledged it, that all condensers do more harm than good; and that when men of better judgement have constructed engines totally without condensers, as good or better than their own, they have just candour enough to admit the fact, and pride and avarice enough to claim them as their invention.

"There is, as your lordship has been abundantly informed, a valve placed in the passage allotted to conduct the steam, water, &c. from the cylinder to the condenser, which alternately opens and shuts this communication. I have to remark that, when the steam regulator, as in Newcomen's engine, opens to the cylinder, and at the same time causes the first jet of steam to discharge the water and air as above described; this valve in Mr. Watt's engine is then open to the condenser; and was there nothing else, the steam would, as well as act on the piston, fly to the condenser, and being there destroyed at that end, if I may so say, would not move the piston at all, it was, therefore, necessary for Mr. Watt to introduce another valve, which he has done. But certain reasons, best known to himself, which the writer of this will not pretend to suggest, induced him to omit giving your lordship and the court an account of it, though, as I have already noted, on the other valve his counsel were very profuse.

"This cunning valve, my lord, is like the injection water smuggled into another part of the engine, and serves, as in the preceding case, to open and shut a communication. It happens, however, not to be the communication between the cylinder and the condenser, but, what is of much greater consequence, it opens and shuts the passage between the boiler and the condenser. I have materially to remark to your lordship respecting this valve, that it must be and is always shut during the time the steam regulator is open. How, then, is it

possible, my lord, that this condenser can be cleansed as in Newcomen's, provided even the former objections did not exist? Thus, having aimed at as much perspicuity as possible, I hope, and am even confident, your lordship, although no engineer, will perfectly understand what I have advanced; and be convinced of the necessity and practicability of giving a full and explicit description of this point also. I shall now proceed as proposed, with some detail on the nature, proportion, and situation of Mr. Wood's very ingenious and valuable application of a pump or pumps for the extraction of the water and uncondensed vapour; which would otherwise much impede the working of the engine, as Mr. Watt, for a wonder, has had the candour to declare in his specification.

"I will here intreat your lordship's patience while I make a solemn protestation. I declare, and I challenge every scientific man to disprove it, that all the improvements which have yet fallen within my observation on Steam Engines, do wholly depend on the application of Mr. Wood's invention, viz. a pump; or, I will at least say, in a proportion of fifty to one compared with the other additions made by Mr. Watt, with all his retinue of doctors, professors, philosophers, mathematicians, and mechanics.

"Now for this pump, the ingenious invention of Mr. Wood. I repeat his name, as your lordship, having heard less about this pump on the present than on former occasions, might be at a loss to judge the cause of this declension, and on this account I shall be more plain on the subject. Much pains were taken on this trial to convince the court that proportion, lateral and altitudal situation, did not at all or not essentially signify; I will therefore confine what I have to say more directly to these points; with a small digression only to consider, as in the case of Mr. Gitty, some remarks from the eminent and ingenious Mr. Cummings, respecting this important article.

"My experience, my lord, obliges me to allow, that when a pump is introduced, or added to one of Newcomen's engines where there is no condenser, a trifling latitude in the size, over and above the real *maximum*, is of little moment, and may be exercised without much detriment to the engine; but I find the closer we adhere to the smallest that is sufficient, the less the power of the engine is impeded by giving it motion.

"As the actual proportion the pump ought to have been to the cylinder must be the result of duly considering the engine both in a perfect and less perfect air-tight state, I will leave every engineer to study for himself as Mr. Watt has done; and hasten to give my reasons why pumps, constructed without regard to proportions, &c. as above mentioned, will not answer in engines made with condensers.

"Suppose, my lord, I constructed an engine on the plan of Mr. Watt, with a steam cylinder exactly equal to one of Newcomen, to which I have annexed a pump of proper size; I should be very naturally led to make this second one from the same patterns; experience having shown me the propriety of its dimensions, and to save also the expense of new patterns, tools, &c. This done, I come to determine the size of my condenser. If I am at a loss in this I go

to Mr. Watt's specification; there I find not a word to help me. I then post off, perhaps, from Manchester to Cornwall, to see a condenser; when I come there I traverse the whole county in the character of a spy, and none will even permit me to enter their works, (and should I intrude without a licence, I should soon get myself expelled,) much less stop the engine and disorganise the whole, to give me the knowledge I am seeking. My own reason, by this time more awake, makes this inference: that, provided I did succeed in meeting with a person friendly enough to suffer my scrutiny, I must of course pay the loss accruing from such an enterprise,—and, for an idea of this, I will refer your lordship to the observations already made on stopping engines. Just as wise, therefore, as when I started, I post back to Manchester, resolved to make a condenser of some sort. I begin by reflecting, not on the thing, for I know not what it is, but on its reputation; and if I chanced to recollect the high encomiums it received in the Courts of Westminster and London, I should be led to conclude, that was my engine all condenser, I could not fail of being on the right side of the question. Thus I determine my condenser shall be (what I have seen some made by Mr. Watt, at the Soho, Birmingham,) as large, or considerably larger than the steam cylinder of the engine for which it is intended. This would be at least twelve or twenty times the dimensions of my pump, but say twelve times for the sake of data; and suppose the engine completed and ready for action: the consequence of this I will endeavour to make plain to your lordship. When the engine has been emptied of her air, and also the condenser, by what Mr. Watt's engineers call blowing through, the steam valve is opened and the piston makes a stroke; then the discharge is made from the cylinder to the condenser by opening another valve. Now, let it be supposed that the uncondensible air or vapour which then fills the condenser, and is to be drawn out by a pump unequal in expansive force to one-twelfth part (and it is seldom less) of the steam's pressure on the piston. The air pump, which I have already said is only one-twelfth part of the contents of this condenser, makes one stroke also; but by this the expansive force of the vapour can only be reduced one-twelfth part, for it must take twelve strokes of this pump to reduce the vapour in the condenser to its least density; and, consequently, there will remain a resistance to the second stroke equal to $\frac{1}{12}$ of the force of the vapour mentioned; and to the next stroke $\frac{2}{12}$ and every continued stroke in this proportion; so that in about thirteen strokes this air and vapour would inevitably become as strong in the condenser as the steam; and, by thus restoring the equilibrium, of necessity stop the engine, although she had nothing but her own materials to carry, and those void of friction."

Making due allowance for the prejudiced feeling with which these remarks of Bramah's were written, arising from the successful rivalry of Watt; our readers will find much interesting information contained in them. It shows clearly the insufficiency and obscurity of the specification in question.

Yet Mr. Watt was a truly wonderful man. His ideas were great,

and many of his discoveries were successful beyond all previous conjecture. He has done more for art and commerce than any single individual ever known: but, whilst we admit all this, we must also say few men would have put their names to many of the inventions which appear under his. All men have, at times, made discoveries, which they imagine to be excellent, but which prove otherwise: but few have put upon record so many absurd and impracticable schemes. What are we to say to his many rotative engines; to his six contrivances for regulating the motion of his engines; to his method of working engines by the alternate expansion and contraction of the steam? That they were most of them impracticable, and some of them the most contemptible schemes that ever entered the brain of a projector. His mind seems to have been capable of any thing; but he was too inactive both in body and mind to set about satisfying himself of the true value of his inventions. Many years elapsed before he submitted his great scheme to the test of experiment; and, when the means *were* afforded, three years passed over before the experiment was completed. Long intervals elapsed between his visits to Soho, even when many of his most important experiments were in progress. We cannot think with Playfair that "he never went either before or beyond the direct inference which could be drawn from an experiment; or that so great was his sagacity, that few bearings of that experiment were omitted or overlooked." We have shown on the contrary that not one half of his schemes answered, and that he, like all men, was liable to misconception and error.

CHAPTER IV.

CONTENTS.—HORNBLOWER'S ENGINE.—BURGESS' ROTATIVE FROM VIBRATORY MOTION.—COOKE'S ENGINE.—BRAMAH AND DICKINSON'S ENGINE.—SADLER'S ENGINE.—CARTWRIGHT'S ENGINE.—HORNBLOWER'S ROTATORY ENGINE.—MURRAY'S BOILER, &C.—MURDOCK'S ROTATIVE ENGINE.—CLOWTHER'S CRANK MOTION.—CARTWRIGHT'S PORTABLE ENGINE.—MURRAY'S AIR PUMP AND VALVES.—BRAMAH'S VALVE.

FROM a wish to keep our description of Mr. Watt's discoveries as connected as we could, we have, until now, passed over the invention of Mr. Jonathan Hornblower, of Penrhyn, Cornwall, for which a patent was taken out in 1781. A full and detailed description is to be found in the first edition of Gregory's Mechanics. The following is a copy of his specification.—

"First,—I use two steam vessels in which the steam is to act, and which in other steam engines are called cylinders. Secondly,—I employ the steam after it has acted in the first vessel to operate a second time in the other, by permitting it to expand itself, which I do by connecting the vessels together and forming proper channels and apertures, whereby the steam shall, occasionally, go in and out of the said vessels. Thirdly,—I condense the steam by causing it to pass in contact with metallic substances, while water is applied to the opposite side. Fourthly,—to discharge the engine of the water employed to condense the steam, I suspend a column of water in a tube or vessel constructed for that purpose, on the principles of the barometer, the upper end having open communication with the steam vessels, and the lower end being immersed in a vessel of water. Fifthly,—to discharge the air which enters the steam vessels with the condensing water or otherwise, I introduce it into a separate vessel, whence it is protruded by the admission of steam. Sixthly,—that the condensed vapour shall not remain in the steam vessel in which the steam is condensed, I collect it into another vessel, which has open communication with the steam vessels, and the water in the mine, reservoir, or river. Lastly,—in cases where the atmosphere is to be employed to act on the piston, I use a piston so constructed as to admit steam round its periphery, and in contact with the sides of the steam vessel, thereby to prevent the external air from passing in between the piston and the sides of the steam vessel."

This patent, like Watt's, conveys no idea of either form or dimensions; and we must therefore have recourse to other sources for more particulars respecting it. We have already said that an enlarged detail is to be found in the first edition of Gregory's Mechanics; but we content ourselves with a shorter one. The first and enlarged account written by Mr. Hornblower, was afterwards omitted by Dr. Gregory, who, in a subsequent edition, makes the following remarks thereon.—"As I have been exposed to much calumny

and misrepresentation for admitting that historic sketch into my work, I beg to remark that I did it *solely* from motives of benevolence. Till the time my second volume was preparing for the press, I knew nothing of Mr. Hornblower; but a friend of mine, on whose judgement I placed great reliance, who was well acquainted with Mr. H. and thought highly of his moral character, as well as of his mechanical skill, had a full persuasion that, through a series of unfortunate circumstances, he had never had justice done him, and urged me to allow Mr. Hornblower to tell his own story. I yielded to his solicitations, and in consequence exposed myself to the malevolence of certain writers, who, in one short note of ten lines,* published *four* positive, wilful falsehoods, for the honourable purpose of injuring my reputation. I, however, forgive them, although they treated me unjustly; and trust they will, ere now, have forgiven me for permitting an injured (though perhaps hasty) man, to defend his own cause and that of his family. He is now beyond the reach of those who wished to promote his welfare, as well as those who, by unfairly depreciating his character, involved him in ruin. His latter years were rendered comfortable, not by the liberality of his countrymen, but by an opulent and scientific *Swede*, who knew how to appreciate and to reward his merit as an engineer."†

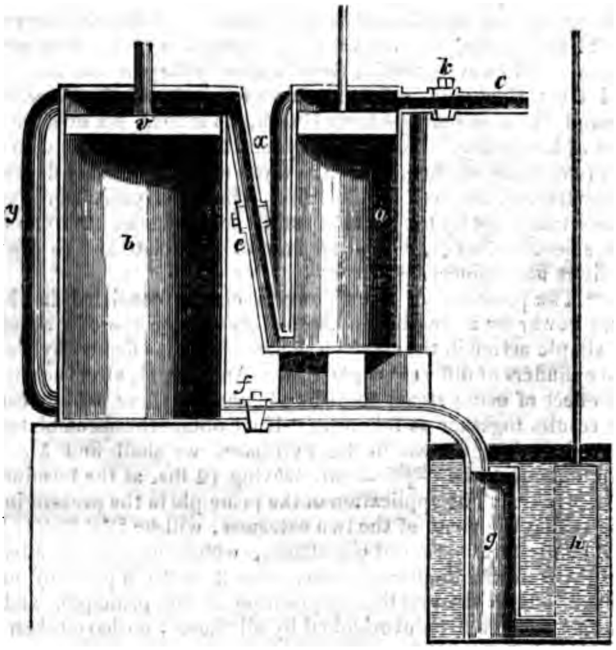
"The principle of Hornblower's engine consisted in obtaining more power by a complicated force of steam than could be acquired by its simple action in the common mode. This is effected by the use of two cylinders of different capacities. And Mr. H, after inquiring into the effect of using steam according to each of these modes, compares the results together as follows. 'If we obtain the accumulated pressure by taking a mean of the extremes, we shall find Mr. Watt's application to be $\frac{24+24+12}{3} = 20$, leaving 12 lbs. at the termination of the stroke. The application of the principle in the present instance, by taking the mean of the two extremes, will be $\frac{24+18}{2} = 21$, leaving 18 at the termination of the stroke; which, in point of advantage, in favor of the double cylinder, is as 3 to 2; a point of no small magnitude in the practical application of this principle, and which seems to have been overlooked by all those who have taken up the subject.'

"The accompanying figure will explain the principle of this engine, which is given without the parts in connection, those being, in common with Watt's engine, already given.—*a b* are the two cylinders; *a* being the smaller one, which has a piston *s* fitted to the interior; this cylinder is in communication with the boiler by the pipe *o*. Other pipes and cocks, *x y*, are attached to each cylinder, and open a communication with both sides of their pistons. *e* is a pipe with a stop cock, which opens a communication between the

* Edin. Review, vol. xiii. p. 327.

† We need scarcely remark here on what must appear evident to all, viz. that, by this short explanation, the Doctor's conduct in this affair rises by his benevolence and generosity of heart far above the malevolent attacks of interested writers; whilst it excites in the breasts of every reader the deepest commiseration for the injuries of the neglected Hornblower.

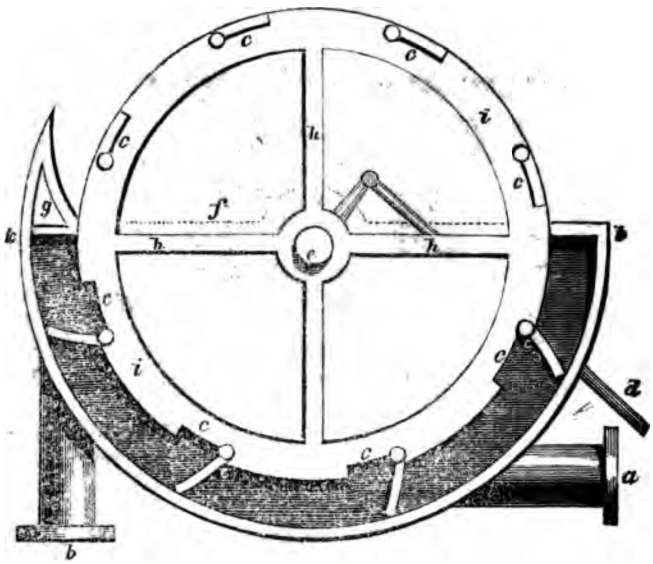
bottom of the cylinder *a*, and the top of the large cylinder *b*. *f* is a pipe and cock leading to the condenser *g*, its pump *h*, placed, as usual, in cold water; these are the same as those used in Mr. Watt's engines. Steam comes from the boiler to the pipe *c*; and its flow may be prevented by the cock *k* to allow the passage of steam from the boiler, and the cocks at *e x y*, to be all open, which will allow the steam to fill both cylinders. The cocks at *x* and *y* must now be closed, *e* and *k* remaining open.



By turning cock *f* a communication is opened between the under side of the piston *v*, and the condenser which forms a vacuum in *b*. The steam pressing on the upper side of *z* in *a*, and the communication between the cylinder *a* under its piston *z* being open, the steam in *a*, from its expansive power, will press *v* downwards in *b*. This decreases the resistance in the under side of the piston *a*, which is also carried downwards by the pressure of the steam flowing through *k* from the boiler; and the two pistons descend at the same time, carrying the beam along with them. When they reach the bottom of the cylinders, the cock *f* shuts off the communication with the condenser, and the cock *e* with the top and bottom of the two cylinders. The cocks in *y* and *x* are now opened, which allows the steam in each a free communication between the upper and under

sides of these pistons, or between that of the last cylinder and condenser; and the counterpoise at the other end of the lever beam raises the pistons to the top of their respective cylinders, or the pipe y may form a communication with the piston and the condenser. x and y are now shut, and e f and k are now opened, and the operation is repeated.

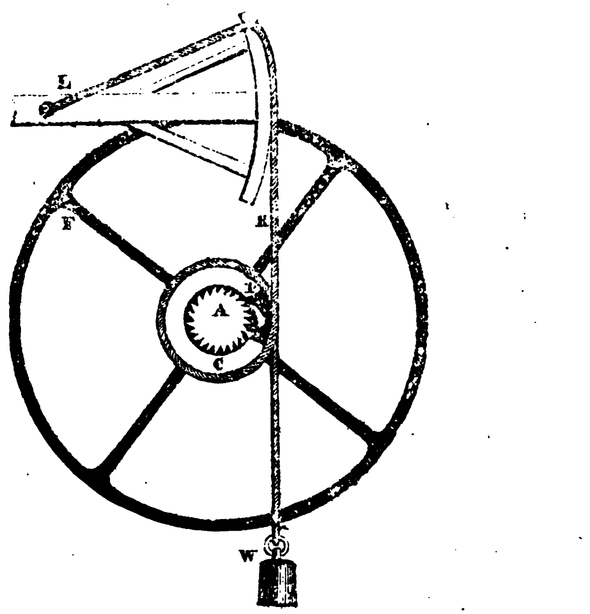
A drawing and description of a rotative engine, by Mr. Cooke, are to be found in the Transactions of the Royal Irish Academy, 1787. We subjoin a description thereof.



On the circumference of a wheel eight vanes or flaps are attached by joints, which are formed to open somewhat more than half of their circumference. During the revolution of the wheel the valves, which are on the lower half of its circumference, hang in a vertical direction by their own gravity. c c c are the valves or flaps; b is the tube which admits steam from the boiler; a a tube leading to the condenser. k k f is the case in which the wheel h h is enclosed as high as the dotted line: this case is to be steam-tight. The wheel being supposed in the situation in the figure, the valves prevent any communication between the boiler and condenser. Steam is now admitted at b, and, pressing on c c, forces them forward in its passage to the condenser and produces movement. The condenser is worked by a crank in the axis, and a rod d is extended from it which keeps a constant vacuum in that half of the steam case:— "by this means a power is added to the steam equal to the weight of the atmosphere; so that, when the force of the steam is only equal to the pressure of the atmosphere, and the valves are six inches

square, the wheel will be forced round by a power equal to 531¼ lbs. placed on its circumference." The construction of this machine we need hardly say would be impracticable. Friction out of the question, the imperfection of the mechanism, and the clumsiness of the whole engine, are too apparent to need any detail.

Mr. Thomas Burgess obtained a patent, in 1789, for a method of producing a rotary motion from the action of an alternate movement. We are induced, from the probability that few of our readers are acquainted with it, to give it a place here.



Upon an axis A, to which the rotary motion is to be communicated, a collar C is accurately fitted so as to turn freely thereupon, and so secured in its place as to prevent its sliding sideways; round the collar a chain or rope R, is to be wound; one end of the rope is made fast to the lever L, of a steam engine, or other alternating moving power, which motion may be horizontal, vertical, or in any other direction: to the other end of the rope a weight W, is suspended, which is to draw the collar C back, in the interval between each stroke or impulse of the moving power. Inside of the barrel or collar C, is fixed a pall or catch, P, which falls by its own gravity into the notches of the axle A, so that, when it is acted upon by the moving power in one direction, the axis A becomes locked to the collar, and the fly wheel F, is forced into a rotary motion. When the action is reversed by the alternating motion of the lever L, the collar is released and runs back, the pall sliding over the notches in

the axis without impediment, the original rotary motion continuing in the fly wheel, by the impetus given it at every alternate stroke of the lever.

This machine needs no comment, it is infinitely inferior to the crank which was in use prior to the date of this patent: it is, notwithstanding, very ingenious; and fifteen or twenty years sooner might have been considered as a convenient and useful method of obtaining the desired end.

In the year 1790, Mr. J. Bramah, of Piccadilly, (author of the pamphlet addressed to Chief Justice Eyre, from which we have made copious extracts,) and Mr. Thomas Dickinson, of Bedworth Close, county of Warwick, jointly obtained a patent for three rotative engines.

Fig. 1 represents the plan of one of these engines, and *Fig.* 2 a section. A A and B B show the ends of two short cylinders or rings of different diameters, one placed in the centre of the other. C is the channel or circular groove, formed between the two circles. The ends of the cylinder or ring B B, are shut up by two flat plates D D, as shown in the section; to these plates is joined an axis or spindle E E, which axis or spindle passes through the ends or caps F F, which enclose the ends of the cylinder or ring A A, and which is made air-tight by means of a stuffing box in the usual way. By this axis or spindle the cylinder or ring B B, may be turned round from without, any external power being applied for that purpose; or this axis or spindle may be applied to give motion to any other machine, when the cylinder B B, is turned round by any power or force acting from within. In the cylinder or ring B B, are fixed two sliders, G G, crossing each other at right angles in the centre where they are notched or half spliced, so far as to allow them to slide backwards and forwards as much, at least, as the diameter of the channel or groove C. The length of each of these sliders is equal to the diameter of the cylinder or ring B B, and one diameter of the channel or groove C, and the width is equal to the height of the channel or groove C; so that the points which perforate the extremity of the cylinder or ring B B, when they are pushed out into the channel or groove, may entirely fill the same, similar to a piston working in a common cylinder; in order that, when the cylinder B B, is turned round, the channel or groove may be by that part of the slider totally swept or emptied. In this channel or groove is fixed the partition H, which fills the same in that part, and, by its being fitted against the periphery of the wheel B B, prevents the passage of any fluid that way round the channel, when the caps or ends are screwed down. On each side of the partition H, is fixed a rib I I, or piece of such a shape as to perfectly fit the circle B B, one quarter of its circumference, between the dotted lines 1 2; and the remaining part is continued in a shape inclining to the circle of the greater cylinder A A, with which it forms an easy juncture at the quartile points, 3 4. When the cylinders B B, with the sliders, are turned round in either direction, the inclined parts of the ribs I I, force the opposite end of the sliders G G, successively into their channel or

Fig 1

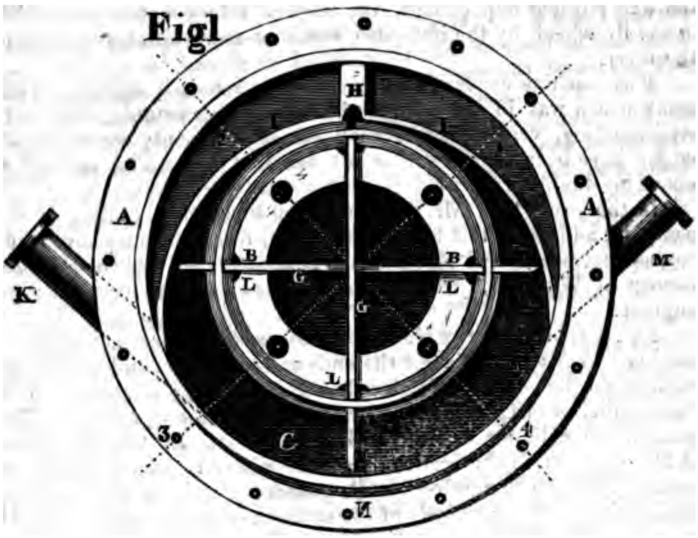
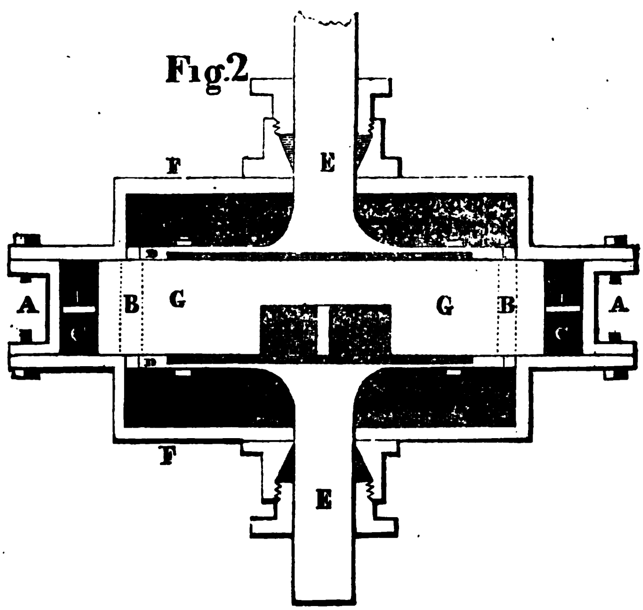


Fig.2



groove, where they are obliged to remain during one quarter of the revolution, being kept in that position by the circular part of the rib

between 1 and 2. K M are two pipes of any required diameter, which may be inserted into the channel or groove, in any direction the situation of the machine may require; between the points H 3 and H 4. The sliders are rendered sufficiently tight at their junction with the channel, by means of oakum or any other flexible material, being forced into the cavities made for that purpose at the parts L L L; and also the partition H, in the same way. The cylinder or ring, B B, being thus armed with the sliders, and the caps or ends, F F, screwed on by the flanches at A A, the machine is complete and ready for action. Now, supposing that through the pipe K a shaft of water, steam, or any other fluid, from any considerable height is admitted into the channel or groove C, it would immediately force against the slider projected in the channel as at N, and also against the fixed partition H; which partition, preventing its passage that way to the evacuation pipe M, where the spent water is discharged, the next slider in succession has passed or covered the junction of the ascending pipe K, so that each successive slider receives the pressure before it is done acting on the former; by this means an uniform rotation is maintained in the cylinder B B, and its velocity will be equal to the descent of the water in the pipe K, and its force equal to the specific gravity of the same. Thus this machine may be worked by steam, condensed air, wind, or any other elastic or gravitating fluid, for the purpose of working mills, or any other kind of machine or engine whatsoever, they being properly connected with the axis or spindle E E; and when any power is externally applied to the said axis, which may turn the machine in any direction, it becomes a complete pump; possessing all the properties of every other sort of hydraulic engine whatsoever, by applying the pipes, K and M, accordingly; and it has also much advantage over every other kind of pump, as the fluid pumped is kept in constant motion both in the suction and ascending pipes. This machine may be fixed either in a horizontal or vertical direction.

It will be perceived that the machine, for which Mr. Job Rider recently obtained a patent, resembles this in principle. The point in which Mr. Rider's differs from it, is in his sliders being more in number, and, instead of crossing each other, are formed of shorter plates not reaching to the axis. The excessive friction of this machine would be a sufficient reason for its abandonment; besides which the cross sliders, G G, would in time become so worn at their ends, that the ribs, I I, would not be able to force them against that part of the cylinder opposite the projection H, so as to stop the passage of the steam.

Fig. 1 represents another plan of a rotative engine in the same patent, where the sliders are stationed in the periphery of the outer cylinder, and the water, steam, or other fluid, passes first into a smaller or inner cylinder, previous to its producing its effect in the channel or groove, as in the other example. A is the end of a hollow smaller cylinder, placed in the centre of the larger cylinder B; the cylinder A, is fixed on an axis or spindle, C, as in the section. D D is the channel or groove, formed between the outer surface of the

Fig 1

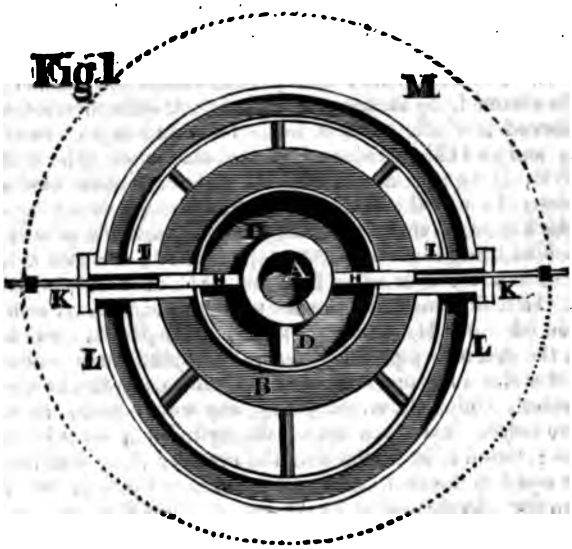
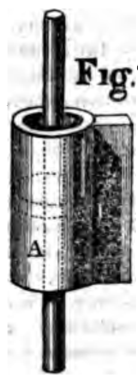


Fig. 2



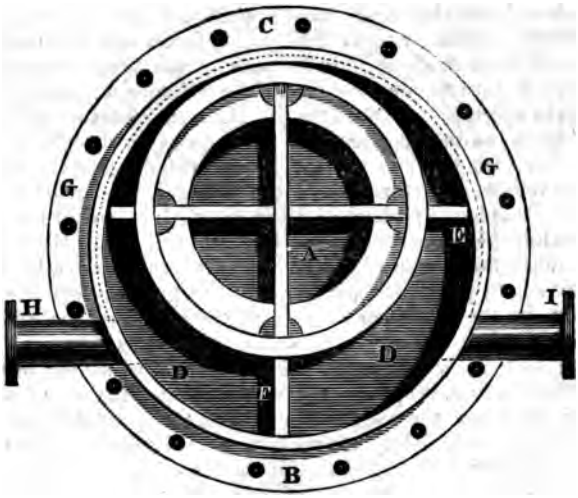
cylinder A, and the inner surface of the cylinder B; to the cylinder A is fixed a wing or fan E, of a projection sufficient to fill and act in the channel D D as a piston, when A is turned round by the axis or spindle C, so as so sweep the contents of the channel; or, when any force is applied on one side of its surface, it will cause the cylinder A, and the axis or spindle C, to be turned round. The cylinder A is left open at both ends, which pass through the plates F F, into the caps, and is fitted water-tight in the junctions. In or about the middle of the cylinder A is a chamber or partition, which divides the upper end from the lower; H H are two sliders, stationed at opposite points in the periphery of the outer cylinder B, where there are cells

projected as at I I, to receive them and allow their motion. These sliders are moved by the small spindles K K passing through stuffing boxes in the usual way. They are ultimately opened and shut by half the rotation of the inner cylinder, by means of a wheel with an eccentric groove fixed on the axis, as L L. In this groove move two friction wheels, which being joined to the sliders by a connecting bar, the sliders H H are opened and shut, by the axis C turning round, so that one of the sliders H H is always close shut against the cylinder A, whilst the other is opening to let the wing or fan pass, which is again shut before the passive slider begins its motion. The machine being thus complete, suppose that, at a pipe O, a current of water, steam, or other fluid having force, was admitted into the cap whilst the machine is in its present position, it would immediately fall into the upper cavity of the cylinder A, and, passing through the aperture into the channel D, would press against the wing or fan E, on the one side, and against one of the sliders H H, on the other; which slider not giving way would cause the wing or fan E to recede, and turn round the cylinder A with its axis C; which axis, turning the wheel with the groove L L, would cause the opposite slider to begin its motion; so that by the time the wing or fan E reaches the station of the slider, it is totally drawn back into its cell, so as to permit the wing or fan E to pass without interruption; and, by the continued motion of the machine, the slider is again shut, before that slider on which the fluid is pressing begins to move; so that, when the first slider, against which the water or fluid is still pressing, is opened, the pressure is then the same between the other slider and the wing or fan E; and the spent fluid between the two sliders immediately rushes through the lower aperture into the bottom of the cylinder A, and is carried off in that way to the open air: thus a uniform rotation will be maintained as in the former example.

This engine is remarkable for simplicity; and if a metallic packing had been at that time known, it might have approximated to a useful rotative engine. As it was, it would be impossible to make hempen packing pass over the grooves for the sliders without being speedily torn out; and also it would be very difficult, if not absolutely impossible, to keep the sliders H against the internal cylinder A, as at each stroke the sliders would rebound from it, and not being kept close by the force of the steam, as in many rotative engines, would soon become loose at the joints, and thereby become ineffective.

The following diagram represents another method by which Messrs. Bramah and Dickenson proposed to obtain a rotative motion. A is a smaller wheel or cylinder, armed with cross sliders, fixed in a larger one B, but, instead of its axis being stationed in the centre of B, as in the previous instances, it is moved as much eccentric as to cause the periphery of A to rub against the side of B, as at C; this causes the channel or groove D D D, to be formed of the shape which appears in the figure. The inner surface of the wheel or ring B is not perfectly cylindrical, but is a curve of such a shape as would be described by the points of the sliders E F being of equal length in the revo-

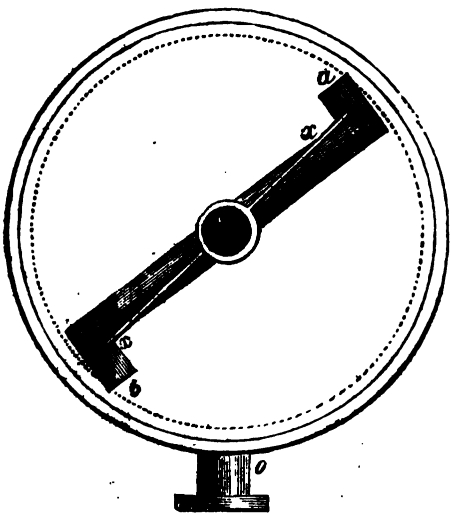
lution of the wheel A; or in other words, of such a shape as would occasion all the four points of the said sliders to be in constant contact therewith. The dotted lines G G show two grooves or cavities, through which the water, steam, or other fluid, contained between the point C and either of the apertures of the pipes H and I, passes into either of the said pipes; which water, steam, or other fluid, would otherwise be pinned up by the slider, and stop the motion of the machine when turned in either direction.



This machine would be liable to the same objections as the first. On the whole these contrivances display great ingenuity, and may be justly considered to rank as high as any that have since been proposed: indeed, there are few rotative engines that have been since projected which do not, in principle, somewhat resemble these: therefore we conclude that, had the genius of the inventor or inventors been exercised when mechanical experience had been advanced, they might in all probability have effected that which is so great a desideratum among modern engineers.

Mr. James Sadler, of Oxford, in 1791, obtained a patent for a rotative engine, which the following drawing and description may serve to illustrate. The steam generated in the boiler is conveyed through the pipe *c*, into the spindle or axis of the rotative cylinder *a b*, which is made steam-tight by working in a stuffing-box. The steam passes along the arms of the revolving cylinder, nearly to its ends, where it meets a jet of cold water, introduced from the hollow axis by the small pipe *s s*; this condensing water falls from the revolving cylinder into the bottom of the case, whence it is conveyed through a pipe, and is discharged by openings made in the ends or

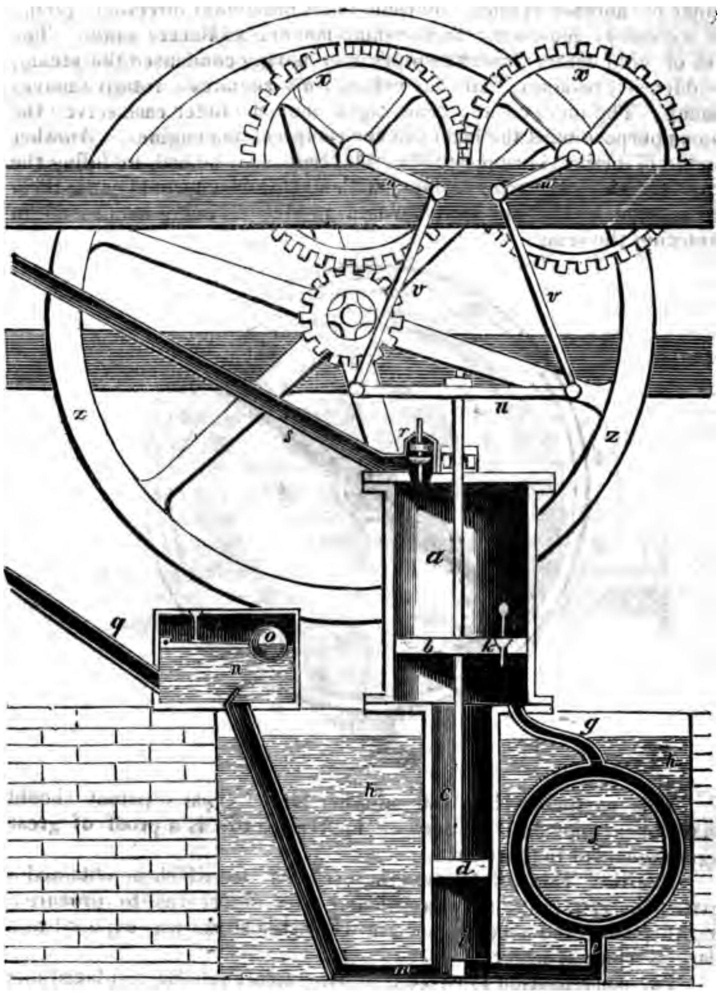
sides of another cylinder moveable in a horizontal direction, giving it a rotatory movement in the same manner as Barker's mill. The jet of cold water from the pipes *x x*, having condensed the steam, produces a re-action, and the cylinder *a b* acquires a rotative movement. The inner case is steam-tight; and the outer case serves the same purpose with the jacket in the reciprocating engines. Another mode of action is suggested by Mr. Sadler to be had by filling the case (in which the arms revolve) with steam, which would cause them to revolve by the pressure it would produce in being condensed in entering the arms.



This engine is Hero's in another form. That a patent should have been taken out for such an ineffective toy is a proof of great ignorance and inexperience.

The Rev. Edward Cartwright's scheme, for which he obtained a patent in 1797, was very ingenious. His object was to procure a tight piston and a condenser, in which the steam was exposed to a large surface of water.

The condensation is effected by two metal cylinders, placed one within the other, and having cold water flowing through the inner one, and enclosing the outer one. Thus the steam is exposed to the greatest possible surface in a thin sheet. Mr. Cartwright likewise has a valve in the piston, by which a constant communication is kept up between the cylinder and condenser, on either side of the piston, so that the condensation is always taking place, whether in the ascending or descending stroke. By this contrivance, steam that may escape past the piston will be immediately condensed, and the vacuum thereby preserved. This was considered to be a decided advantage over the general mode of arranging the valves, which does not always provide for the restoration of a vacuum destroyed by the imperfection of the packing. K



"The piston *b* moving in the cylinder *a*, has its rod prolonged downwards; another piston *d* is attached to it, moving in the cylinder *c*, and which may be also considered as a prolongation of the steam cylinder. The steam cylinder is attached by the pipe *g* to the condenser, placed in cold water, formed of two eccentric circular vessels, between which the steam is admitted in a thin sheet, and is condensed by coming in contact with the cold sides of the condensing vessel. The water of condensation falls into the pipe *e*. To the bottom of the cylinder *i*, a pipe *m* is carried into a box *n*; having a float-ball *o*, which opens and shuts the valve *p*, communicating with

the atmosphere : a pipe *q* is also fitted to the box. There is a valve placed at *i*, opening into the cylinder *c*; another at *n*, also opening upwards. The pipe *s* conveys steam from the boiler into the cylinder, which may be shut by the fall of the clack *r*. *k* is a valve made in the piston *b*.

In the figure the piston *b* is shewn as descending by the elasticity of the steam flowing from the boiler through *s*: the piston *d* being attached to the same rod is also descending. When the piston *b* reaches the bottom of the cylinder *a*; the tail or spindle of the valve *k* being pressed upwards, opens the valve, and forms a communication between the upper side of the piston and the condenser; at the same moment the valve *r* is pressed into its seat by the descent of the cross arm on the piston, which prevents the further admission of steam from the boiler; this allows the piston to be drawn up to the top of the cylinder, by the momentum of the fly-wheel *z*, in a non-resisting medium. The piston *d* is also drawn up to the top of *c*, and the valve *i* is raised by the condensed water and air which have accumulated in *e*, and in the condenser *g*. At the moment when the piston has reached the top of the cylinder, the valve *k* is pressed into its place by the pin or tail striking the cylinder cover; and at the same time the piston *b* striking the tail of the valve *r*, opens it; a communication is again established between the boiler and piston, and it is forced to the bottom as before. By the descent of the piston *d*, the water and air which were under it in the cylinder *c*, being prevented from returning into the condensing cylinder, by the the valve under *i*, are driven up the pipe *m*, in the box *n*, and are conveyed into the boiler again through the pipe *q*. The air rises above the water in *a*; and, when by its accumulation its pressure is increased, it presses the float *o* downwards; this opens the valve *p*, and allows it to escape into the atmosphere."

This most ingenious machine, it appears, was tried first at Cleveland Street, Mary-le-bonne, and afterwards at Horsleydown, at both of which places it is said to have given great satisfaction. These trials must have been much more decisive than any opinion; and although we have not been able to ascertain further respecting the success of the engines when put in practice, than the simple fact of their having been approved of by the respective proprietors, our own judgment warrants a conclusion, that this plan is admirably adapted to be applied where a small engine is necessary. The objection against the mode of condensation adopted by Mr. Cartwright, was subject to great objection previous to experiment; so much so, that one of the greatest engineers this country ever produced, was heard to state it as his opinion, that "were a pipe to be laid across the Thames, the condensation would not be quick enough to work a steam engine with its full effect." It was shewn, however, when tried, that this opinion was incorrect, as the condensation was very rapid, and the vacuum tolerably good.

Not the least ingenious part of Mr. Cartwright's patent was the metallic piston, which has been of late years very generally used. Though this kind of piston is now somewhat differently modified from

the whole force of the machine. To provide against the least retrogate motion whatever, when the levers may be partly worn from friction, they are furnished with springs between them and the outer extremity of the channel, so that the two bearing points may at least touch their respective fulcrums.

This was Hornblower's rotatory engine. It, too, as we shall shew, has been patented as an original invention many years subsequently to the date. It would be no unnecessary digression to shew here the necessity of some work which contained a chronological description of anything which has been attempted (and howsoever insignificant) in the form of steam engines. In the Repertory of the Arts there has, from the commencement, been inserted a description of most professed improvements on the steam engine; but this work is too scarce, too voluminous, and too expensive, to be in the hands of many.

The objection to this machine appears to be that the two diaphragms *c* would soon destroy each other; for whilst one remained stationary, the other having no check would strike forcibly against it: now to retard this check would be to produce an irregular motion, because as the motion is communicated directly to the external machinery, any decrease in the speed of the diaphragm would also produce a decrease of speed in the machine throughout: and if the speed of the diaphragm be kept up it would strike violently against that one which is at rest.

Mr. Matthew Murray, of Leeds, a gentleman, whose name will be familiar to most of our readers as a steam engine manfacturer of celebrity, obtained a patent, in 1799, for saving fuel and lessening the expense of engines. He proposed to effect the first object, by having a small cylinder upon the boiler, to which he fitted a piston and rack: this rack worked a wheel upon a spindle, which spindle passed through the chimney, where was a damper, which had free liberty to turn round. As the steam increased in the boiler beyond the necessary force, it forced up this piston and rack, which acting upon the spindle, closed or partially closed the damper, and thereby lessened the draught of the fire, by which the consumption of the coal was reduced, until the superfluous steam was wrought out of the boiler, when a weight which had been wound up by the rise of the piston descended, and allowed the damper to return to its former position.

The other object, namely, decrease of cost, will be better elucidated by the words of the specification. "I cause the steam or atmosphere to act upon pistons moving in long pipes or cylinders, lying in a horizontal direction. These pipes may be square or round, and of any length required, but must lie in a horizontal direction, which is the principle here stated. By which contrivance, a more convenient motion can be applied to mill work, and a much longer stroke can be obtained than in the usual way.

Next. I cause the pistons moving in the above pipes or cylinders, by their reciprocating motion, to produce a circular or rotative motion of equal power, by means of screws, racks, and wheels,

applied in such a manner as to cause the power of the engine to fix alternately the wheels necessary for producing motion, in perpendicular or horizontal directions.

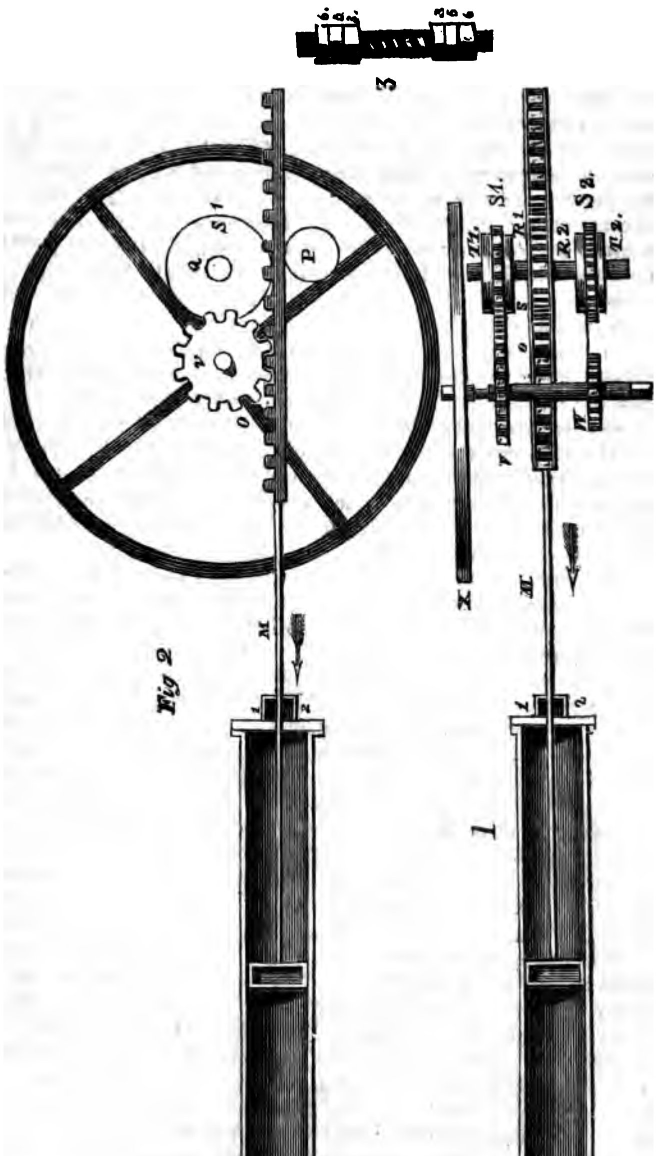
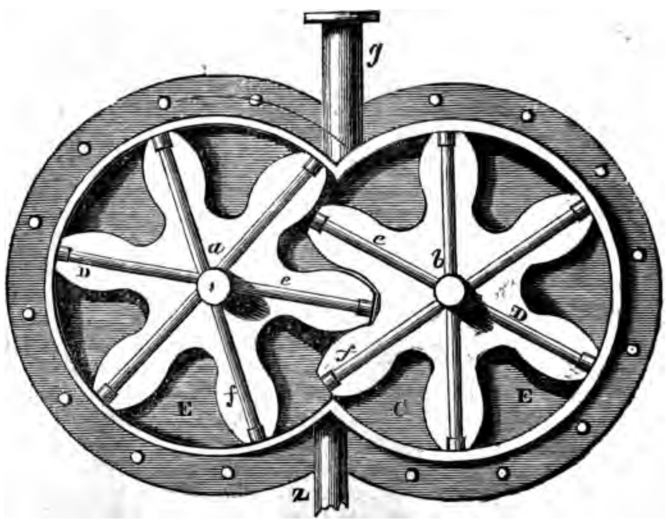


Fig. 1 and 2, two horizontal cylinders, containing pistons; M M the piston rods. *Figs*. 1, 1, inlets for the steam from the boiler and atmosphere; 2, 2, outlets for the condensed steam or atmosphere; N, a roller for bearing the piston. These pipes or cylinders must be firmly fixed down to a stone platform, or iron cistern, or any kind of firm and secure fixing.

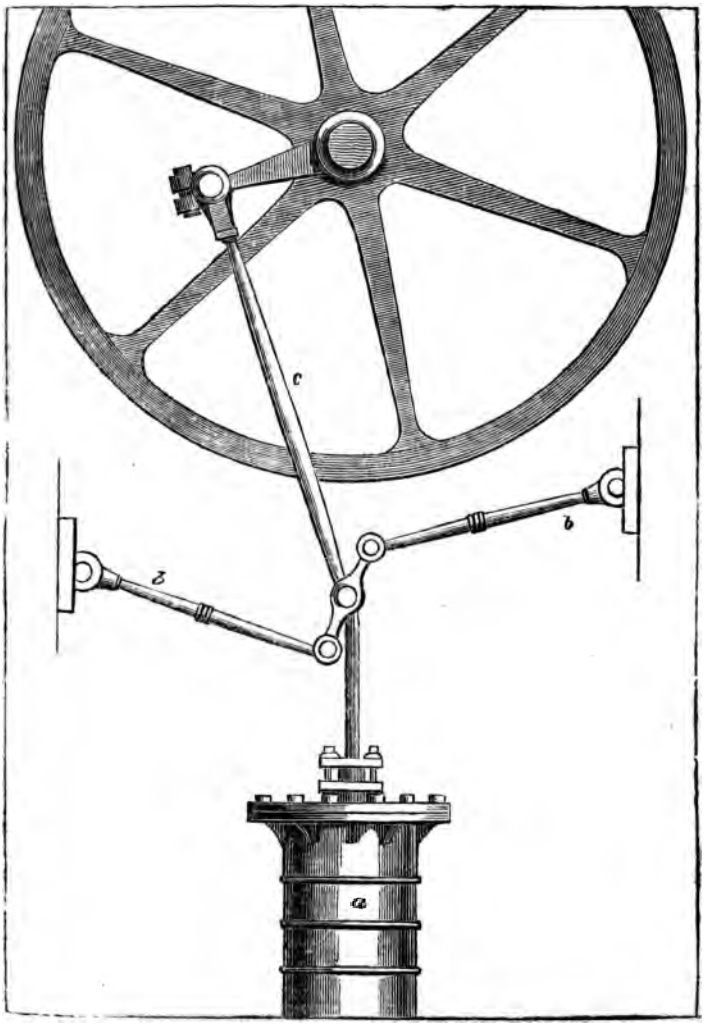
O (*Fig*. 1 and 2) is a rack, fixed to the piston rod M, and moving upon the roller P; Q is a socket wheel with teeth, working in the rack O; the inside of the socket wheel Q is screwed to fit the *middle* of the axletree; R 1 and R 2, (*Fig*. 1.) are plain wheels, put loose on the *square* of the axletree; at S 1 and S 2, are tooth wheels, put loose upon the *round* part of the axletree. T T, are plain wheels, acting as abutments, put fast upon the axletree. On an axletree or rotative shaft, for giving motion to the mill work, are fixed the wheels V and W; X a small fly wheel, for regulating the motion.

Now the effect or motion of this machine is, that when the piston, and piston rod, and rack O, are impelled by the steam or atmosphere in the direction of the arrow, the socket wheel Q, turns upon the screwed part of the axletree, and with its ends, presses (by the force or power of the engine) the loose wheel S 1 between the wheels R and T, by which means, the wheel V is turned with the same velocity as the screwed wheel Q, while the wheel S 2 is at liberty upon the axle; in which situation the whole continues, till the piston arrives at the end of the long pipe or cylinder, when the piston is changing motion and going in the contrary direction to the arrow, the rack O turns the wheel Q in the opposite direction, sets at liberty by the former means the wheel S 1, and fastens the wheel S 2, which gives the same motion to the wheel W, by means of the intermediate wheel B.*



* Repertory of the Arts.

Mr. W. Murdock, of Redruth in Cornwall, obtained a patent in 1799, for a better method of boring cylinders, and for casting the steam case of Watts's engine in one entire piece, to which the top and bottom of the cylinder are attached. He also proposed to cast the cylinder and steam case of one piece of considerable thickness, and *bore a "cylindric interstice" between the case and cylinder, leaving them attached at one end !!!* In another part he proposes to simplify the construction of the valves of the condensing engine, by connecting the upper and lower valves so as to work with one spindle or rod;



the rod which connects them being tubular answers as an eduction pipe to the upper end of the cylinder.

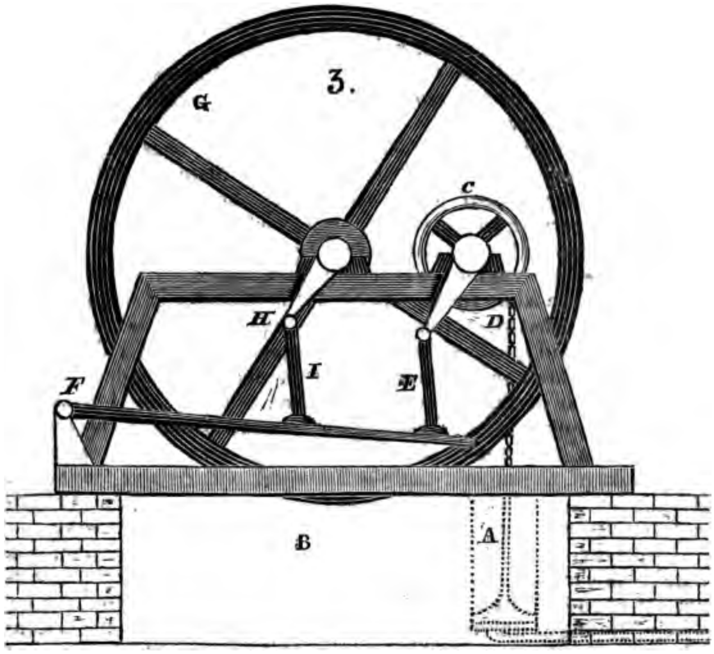
But the most notable invention here described is a rotative engine, which consists of two toothed wheels working into each other, and fitted into a double case resembling two cylinders with a segment cut off each. *a b*, are the two axes upon which the two wheels D D are fixed. The teeth are supposed to be packed at the parts in contact with the exterior cylinder. The teeth which are in contact are so fitted as to prevent any escape in that direction. Steam being introduced at the pipe *z* a rotative motion would be produced; but the construction would be so defective, and the friction so great, as totally to prevent its ever answering in practice. At the same time we ought to correct an erroneous opinion which many have formed respecting this machine, which is, that it would not move at all; it being thought that as the surface of the teeth *e e* are as great as that of *f f*, that there would be as great a tendency to turn one way as another, and therefore no motion would be produced. But it will be seen that as the teeth *e e*, though individually of equal superficies with *f f* overlap each other, the surface presented to the action of the steam is only equal to one tooth, therefore the effect of the steam (without calculating friction) would be one half of the real force.

In the year 1800, Mr. Phineas Crowther, of Newcastle upon Tyne, obtained a patent for a method of dispensing with the beam of reciprocating engines by placing the fly wheel immediately above the piston. *a* represents the cylinder; *b b* the parallel motion; and *c* the connecting rod. The principle will be seen by a slight inspection of the drawing without further explanation. Mr. Crowther constructed several good engines on this plan which were found to succeed very well.

The Rev. Edward Cartwright obtained a patent for a Portable Engine in 1801, of which the following is a description.

It consists, first in so disposing the different parts of the Steam-Engine as that the boiler, the cylinder, the fly wheel, and all the moving parts of the engine, shall be embraced by, comprehended within, or attached to a frame erected upon the boiler, and so connected together as to make one whole or perfect machine; so compact as to be easily portable; and requiring no farther trouble and expense, after it is finished at the manufactory, than to place it upon the fire, when it will be immediately ready for the office for which it is intended; for this purpose it will be most convenient to make the boiler oblong, and straight-sided, with a flat top, placing the cylinder within the boiler, a position which has, indeed, been already adopted by others, though for a different purpose. The frame extends lengthways on the sides of the boiler, and may project a little beyond that end of the boiler where is fixed the air-pump and condenser. To the part of the frame so projecting, the air-pump and condenser may be attached or suspended. Across the frame is an axle, with a pulley upon it, round which goes a chain or strap, to the top of the piston rod. Upon this axis is a crank, from which goes a connecting-rod to a lever, lying horizontally on the top

of, or alongside the boiler. Besides the axis above-mentioned, there is another axis lying across, either immediately above or below, or on one side, of the former one. Upon this axis, which is the axis of the fly-wheel, is a crank, from which goes a connecting rod to the same lever, that was spoken of before.



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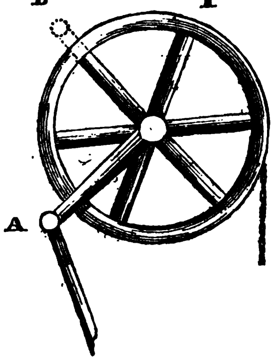

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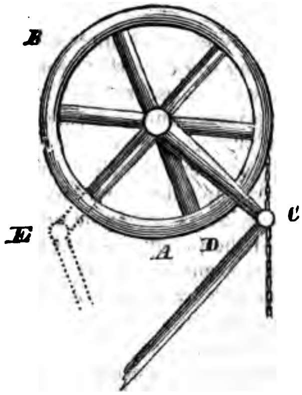


Now it is evident, that when the pulley is put in motion by the action of the piston, the crank upon its axis will move the crank upon the axis of the fly-wheel, as they are both connected to the same lever. If, therefore, the pulley is made to move in a direction from A to B, *(see Fig.* 1.*)* and back again, by the action of the piston, and its counterweight; and if the crank upon its axis moves in the same direction likewise, the crank upon the axis of the fly-wheel will also do the same, unless it is made, as it must be, of such a determinate length as that when it reaches the extremity of its motion it can pass forwards; in that case a rotatory motion is produced on the fly-wheel. Again, if the crank upon the axis of the pulley is so disposed as that when the pulley moves from A to B, or through any space not exceeding a complete revolution, *(see Fig.* 2.) the crank shall pass from C to E, through D, or in that direction, according to the space through which any given point of the pulley passes the crank will give two vibrations to the lever for one stroke of the engine, which will give two revolutions of the fly-wheel in the same time. Again, if the diameter of the pulley be so reduced as that the stroke of the engine shall make the pulley revolve once and a half round and back again, the crank will occasion the lever to vibrate three times for every stroke of the engine. Again, if the diameter of the pulley be so reduced as that it shall make two complete revolutions, and back again, for one stroke of the engine, in that case the crank will give four vibrations to the lever for one stroke of the engine, and the fly-wheel will revolve four times. By this invention the fly-wheel may be made to run with any requisite velocity without the intervention of any kind of wheel-work.

Secondly. For the purpose of lessening the waste of power, and regulating the velocity of the engine, instead of making the governor act upon the throttle valve, by causing it to give motion to a wedge, sliding at liberty backwards and forwards, under the weight which keeps the steam valve open. If in any particular case it should be thought convenient to have the fly-wheel below, its axis must be placed underneath the lever, connecting it to the lever by a rod as before.

Thirdly. When a reciprocating motion is required horizontally the connecting rod of either crank is extended as far below; the lever as may be necessary, and at the bottom; that which is wanted to have a reciprocating motion hangs to it in a joint.

The air pump, as well as any other pump that may be wanted, is worked by a lever, which receives action by the piston. And to such lever is applied the necessary counterweight.

If the engine is a double one, there must be a double chain or strap round the pulley, so that the piston may act upon the pulley both in its descent and ascent. Or the action may be given to the axis of the crank by a rack and pinion.

A, the cylinder.

B, the boiler.

C, pulley put in motion by the piston aad its counterweight.

D, the crank upon the axis of the pulley.

E, the connecting rod.
F, the lever.
G, the fly-wheel.
H, the crank upon its axis.
I, rod connecting it to the lever F.*

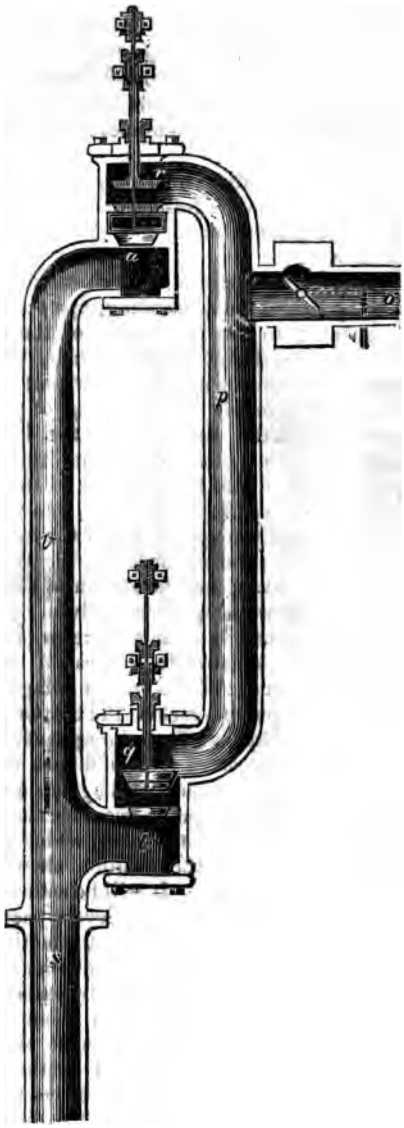
This engine is portable and cheap, but we think it falls short of Mr. Cartwright's former scheme for ingenuity; we dislike racks and pinions where they can possibly be avoided; neither do the chains deserve, in our opinion, more commendation. Both these plans are inferior, in our judgment, to many engines in actual use at the date of this patent.

Mr. Matthew Murray's patent of 1801, contained more meritorious and useful schemes than his former patent, most of them being generally in use at the present day. We shall describe his valves, commonly called nozzles.

o, in the present figure,' is the pipe conveying steam from the boiler, and delivering it into the descending pipe *p*, which terminates in the valve *q*, opening to the lower part of the cylinder by the side opening marked as a shaded parallelogram, while the valve *r* opens a similar communication with the upper part of the cylinder, so that by the successive opening and shutting of *q* and *r*, steam is admitted above and below the piston: *s* is the lower end of the eduction pipe, joining on to the condenser, and this pipe opens first to the lower part of the cylinder by the valve *t*, and leads also by a perpendicular continuation of the same pipe *v*, to a valve *u*, by which a connection is formed with the upper part of the cylinder. The two apertures into the cylinder, called nozzles, are therefore common both to the admission of steam, and formation of the vacuum, which is regulated simply by the working of the valves. For as the figure now stands, *r* is the only open valve in the steam pipe, consequently steam would enter above the piston to depress it, while a vacuum would exist below it on account of the valve *t* being open to the condenser. As soon as the piston reaches the bottom of the cylinder, the valves *r* and *t* must be shut, and *u* and *q* opened, when the steam being no longer able to get through *r*, would pass down the pipe *p*, and enter the lower part of the cylinder through *q*; meantime, *u* being open to the condenser by the pipe *v*, would cause the necessary vacuum above the piston to permit its ascent, which being completed, the valves must be again put into the position shewn in the figure, to produce its descent, and so on. It will be sufficient to state that these valves are operated upon, either by levers passing in a steam-tight manner through the side pipes, or that sometimes the spindles of the valves are made to act one through the other in stuffing, as in the present instance, when they are worked by external applications. It is likewise not unfrequent to connect a steam and condensing valve, when they are required to open and shut simultaneously by an external rod. Motion is communicated to the valves in such engines as are without a fly-wheel, by a rod, or beam, attached to the engine beam, very near to the cylinder end of it, and called a plug-

* Specification of Patent 1801.

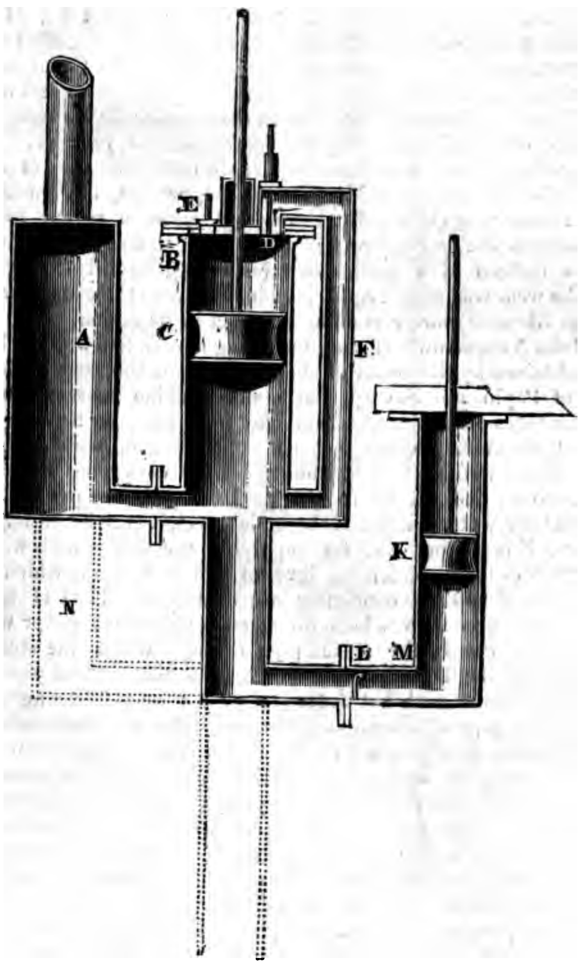
tree; this plug-tree is equipped with certain adjustable projections, called tappets, which strike the levers or handles of the valves, and thus open and shut them at the proper intervals as they rise and fall with the beam.*



* Millington's Epitome.

By this most ingenious contrivance no waste of steam arises, excepting in the small aperture between the valves; the friction is likewise much less than either slides, cocks, or indeed any other kind of valve—the only resistance to their motion being the pressure upon the upper side by the steam, when in their seats. Their cost, compared to that of the slide-valve, is much greater, but as they are not liable to wear, and work with great accuracy, the extra expense does not prevent their very general adoption for large engines.

At the same time Mr. Murray described a new air-pump, in which the air in the condenser was discharged from the air-pump without



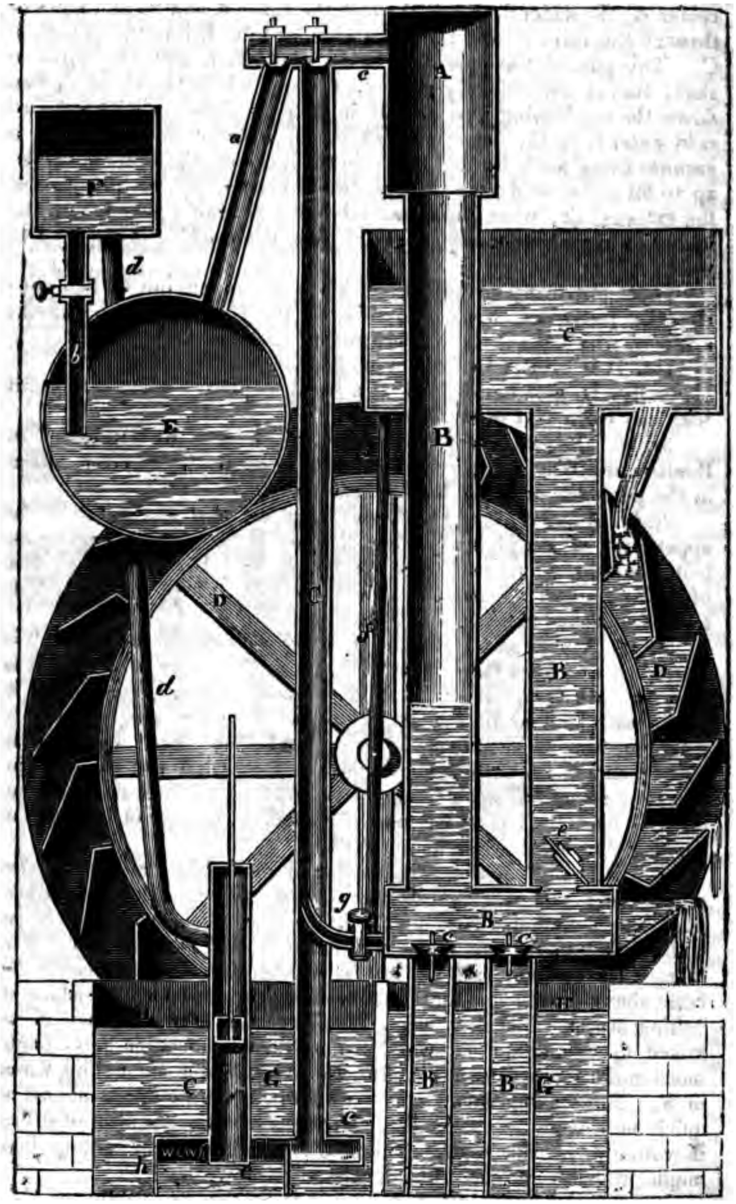
an effort to open the valves, or press through a body of water, and in which the air and water were discharged, separately, in different ways; this he effected by discharging the air alone by one bucket, and the water alone by another, or by an eduction pipe of 28 feet in length. A represents the condenser; B the air-pump; C the air piston; D the air valve which is opened and shut by the working parts of the engine, and has an elastic rod; E the valve for discharging the air; F the exhausting pipe, having a free communication betwixt the condenser and the top of the air pump, when the valve D is open; G the eduction pipe; K a bucket for lifting the water upwards as in a common pump; L a foot valve for preventing a return of the water during the descent of the bucket K; M the barrel of the pump for discharging water alone. This, together with an inspection of the preceding diagram, will serve to shew the nature of his invention. The utility of the separate discharge of the air and water is unquestionable; but whether this will compensate for the increased expense and complexity can only be ascertained in practice. Mr. Murray's scheme, however, has been again made the subject of a patent, a short time ago, by Mr. George Stephenson, of Newcastle.

In the same year (1801) Mr. Bramah obtained a patent for an improvement in the fourway cock, by causing it to make a continuous revolution instead of a partial one (as used previously). By this method the wear was more regular, which rendered the cock durable, and it was likewise more certain and correct in its action.

Mr. John Nuncarrow's engine, for giving motion to a water-wheel, by a fall obtained by the power of steam, acts upon the same principle as those of Papin and Savery, but as his machine possesses many great advantages over theirs, we shall offer no apology for its insertion.

A is the receiver, which may be made either of wood or iron. B B B B B are wooden or cast iron pipes, for conveying the water to the receiver, and thence to the penstock. C the penstock or cistern; D the water wheel; E the boiler, which may be either iron or copper; F is the hot well for supplying the boiler with water; G G are two cisterns under the level of the water, in which the small bores B B and the condenser are contained. H H H is the surface of the water with which the steam engine and water wheel are supplied; *a a* is the steam pipe through which the steam is conveyed from the boiler to the receiver; *b* the feeding pipe, for supplying the boiler with hot water; *c c c c c* the condensing apparatus; *d d* the pipe which conveys the hot water from the condenser to the hot well; *e e e* valves for admitting and excluding the water; *f f* the injection pipe, and *g* the injection cock; *h* the condenser.

It does not appear necessary to say any thing here on the manner in which this machine performs its operations without manual assistance, as the method of opening the cocks, by which the steam is admitted into the receiver and condensed, has been already well described by several writers. But it will be necessary to remark, that the receiver, penstock, and all the pipes, must be previously filled before any water can be delivered on the wheel; and when the steam in the boiler has acquired a sufficient strength, the valve as at *c* is open,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and the steam immediately rushes from the boiler at E into the receiver A, the water descends through the tubes A and B, and ascends through the valve *e*, and the other pipe or tube B into the penstock C. This part of the operation being performed, and the valve *c* shut, that at *a* is suddenly opened, through which the steam rushes down the condensing pipe *c*, and in its passage meets with a jet of cold water from the injection cock *g*, by which it is condensed; a vacuum being made by this means in the receiver, the water is driven up to fill it a second time through the valves *e e*, by the pressure of the external air, when the steam valve at *c* is again opened, and the operation repeated for any length of time the machine is required to work.

There are many advantages which a steam engine on this construction possesses, beyond anything of the kind hitherto invented; a few of which the inventor thus enumerates:—

1st. It is subject to little or no friction.

2ndly. It may be erected at a small expense, when compared with any other sort of steam engine.

3rdly. It has every advantage which may be attributed to Boulton and Watt's engines, by condensing out of the receiver, either in the penstock or at the level of the water.

4thly. Another very great advantage is, that the water in the upper part of the pipe adjoining the receiver acquires a heat by its being in frequent contact with the steam, very nearly equal to that of boiling water: hence the receiver is always kept uniformly hot, as in the case of Boulton and Watt's engines.

5thly. A very small stream of water is sufficient to supply this engine (even where there is no fall), for all the water raised by it is returned into the reservoir H H H. From the foregoing reasons it would seem that no kind of steam-engine is better adapted to give rotary motion to machinery of every kind than this. Its form is simple, and the materials of which it is composed are cheap; the power is more than equal to any other machine of the kind, because there is no deduction to be made for friction, except on account of turning the cocks, which is but trifling.

But it should be observed on the other hand, that one of the properties of this machine, enumerated by the inventor as an advantage, would be found more a defect than otherwise; we allude to the water in the upper part of the pipe being heated by the steam. For though less steam would be lost by condensation, yet it should be remembered that it is impossible to form a vacuum on the surface of boiling water. The only way, therefore, that the water would be raised up the column B, would be by the condensation in C being more rapid than the steam could be generated from the boiling water in B. But we apprehend steam would be generated thus almost as quick as it could be condensed, and therefore the operation of filling B would prove very slow. The addition of a non-conducting float might probably, in part, obviate this objection.

CHAPTER V.

CONTENTS.—ORIGIN OF THE STEAM BOAT.—EVANS'S ENGINE AND EXPERIMENTS. ROBERTSON'S ENGINE.—TREVETHECK AND VIVIAN.—MURRAY'S PORTABLE ENGINE.—WILCOX'S IMPROVEMENTS.—WOOLFE'S BOILER, &c.—HORNBLOWER'S STEAM WHEEL.—BOAZ' IMPROVEMENTS ON SAVERY.—TROTTER'S ROTATIVE ENGINE.—FLINT'S ENGINE.—WILCOX'S ROTATORY ENGINE.—MAUDSLEY'S PORTABLE ENGINE.

Our history is now brought down to the time in which the minds of ingenious mechanics were actively engaged in the project of applying the steam engine to propelling vessels. The idea had, as we have shown, been entertained both by Savery and Hulls, the latter of whom obtained a patent for the application of the crank to Newcomen's engine, with the expectation of carrying his plan into effect by this means. But the steam engine was at that date too imperfect to admit of success; and we cannot, therefore, attach greater importance to the schemes of these individuals, than we should to the projects of numberless other men to whom the idea had, no doubt, frequently occurred long before the steam boat was brought into successful operation. Who the person was that made the first attempt to carry into effect this most important improvement, has, like most such meritorious inventions, become the subject of dispute. It appears that the earliest experiments tried in England were in 1801: but if we may credit the statements of a most ingenious mechanic, (Mr. John Evans, of America,) it appears he had published a description of a method of driving boats by steam, in 1785. Untoward circumstances prevented Mr. Evans from carrying his plan into effect until 1804; but he does, in our opinion, fully establish his claim to the first contrivance of a *practicable* steam boat. We shall insert Mr. Evans's own account of the commencement and progress of his ideas and experiments, as we consider them sufficiently important to merit every publicity.

"About the year 1772, being then apprenticed to a wheelwright, I laboured to discover some means of propelling land carriages, without employing animal power. All the modes that have since been tried, (so far as I have heard of them,) such as the wind, treadles with ratchet wheels, cranks, &c. to be worked by men, presented themselves to my mind; but were considered as too futile to deserve an experiment: and I concluded that such motion was impossible, for want of a suitable original power.

"But one of my brothers informing me, on a Christmas evening, that he had that day been in company with a neighbouring blacksmith's boys, who, for amusement, had stopped up the touch-hole of a gun-barrel, then put into it about a gill of water, and rammed down a tight wadding; after which they put the breech-end of it

into the smith's fire, when it discharged itself with as loud a crack as if it had been loaded with gunpowder.

"It immediately occurred to me that there was a power capable of propelling any waggon, provided that I could apply it; and I set myself to work to find out the means of doing so. I laboured for some time without success, at length a book fell into my hands, describing the old atmospheric engine. I was astonished to observe that they had so far erred as to use the steam only to form a vacuum, to apply the mere pressure of the atmosphere, instead of applying the elastic power of the steam for original motion; a power which I supposed was irresistible. I renewed my studies with increased ardour, and soon declared that I could make steam waggons; and endeavoured to communicate my ideas to others; but, however practicable the thing appeared to me, my object only excited the ridicule of those to whom it was known. But I persevered in my belief; and confirmed it by experiments, that satisfied me of its reality.

"In the year 1786 I petitioned the legislature of Pennsylvania, for the exclusive right to use my improvements in flour-mills, as also steam waggons, in that state. The committee, to whom the petition was referred, heard me very patiently while I described the mill improvements; but my representations concerning steam waggons made them think me insane. They, however, reported favourably respecting my improvements in the manufacture of flour; and passed an act, granting me the exclusive use of them, as prayed for. This was in March, 1787, but no notice is taken of the steam waggons.

"A similar petition was also presented to the Legislature of Maryland. Mr. Jesse Hollingsworth, from Baltimore, was one of the committee appointed to hear me, and report on the case. I candidly informed this committee of the fate of my application to the legislature of Pennsylvania, respecting the steam waggons, declaring at the same time, without the encouragement prayed for being granted to me, that I would never attempt to make them; but that, if they would secure to me the right as requested, I would, as soon as I could, apply the principle to practice: and I explained to them the great elastic power of steam, as well as my mode of applying it to propel waggons. Mr. Hollingsworth very prudently observed, that the grant could injure no one; for he did not think that any man in the world had thought of such a thing before; he therefore wished the encouragement might be afforded, as there was a prospect that it would produce something useful. This kind of argument had the desired effect; and a favourable report was made May 21st, 1787, granting to me, my heirs, and assigns, for 14 years, the exclusive right to make and use my improvements in flour mills, and the steam waggons, in that State. From that period I have felt myself bound in honour to the State of Maryland, to produce a steam waggon as soon as I could conveniently do it.

"In the year 1789 I paid a visit to Benjamin Chandler & Sons, clock-makers, men celebrated for their ingenuity, with a view to induce them to join me in the expense and profits of the project; I

showed to them my drawings, with the plan of the engine, and explained the expansive power of steam; all of which they appeared to understand: but, fearful of the expense and difficulties attending it, declined the concern. However, they certified that I had shown them the drawings, and explained the powers of high-pressure steam, &c.

"In the same year I went to Ellicott's mills, on the Patapses, near Baltimore, for the purpose of endeavouring to persuade Messrs. Jonathan Ellicott and Brothers, and their connections, (who were equally famous for their ingenuity,) to join me in the expense and profits of making and using steam waggons. I also showed them my drawings, and minutely explained to them the powers of steam; they appeared fully to comprehend all I said; and, in return, informed me of some experiments they themselves had made, one of which they showed me. They placed a gun-barrel, having a hollow arm, and a small hole on one side, at the end of the arm, similar to Barker's rotary tube mill: a little water being put into this barrel, and fire applied to the breech of it, the steam issued from the hole in the end of the arm with such force, as, by re-action, to cause the machine to revolve, as I judged, about one-thousand times in a minute, for the space of about five minutes, and with a considerable force for so small a machine. I tarried here a few days, (May 10th and 11th, 1789,) using my best efforts to convince them of the possibility and practicability of propelling waggons, on good turnpike roads, by the elastic power of steam. But they also feared the expense and difficulty of the execution, and declined the proposition. Yet they highly esteemed my improvements in the manufacture of flour, and adopted them in their mills, as well as recommended them to others.

"In the same year I communicated my project, and explained my principles, to Levi Hollingsworth, Esq. now a merchant in Baltimore. He appeared to understand them; but also declined a partnership in the scheme, for the same reasons as the former persons.

"From the time of my discovering the principles, and the means of applying them to use, I often endeavoured to communicate them to those I believed might be interested in their application to waggons or boats; but very few could understand my explanations, and I could find no one willing to risk the expense of the experiment.

"In the year 1785, or 1786, before I had petitioned the legislature, I fell into company with Mr. Samuel Jackson, of Redstone; and learning of him, that he resided on the Western Waters, I endeavoured to impress upon his mind the great utility and high importance of steam-boats, to be impelled on those waters. Telling him that I had discovered a steam-engine so powerful, according to its weight, that it would, by means of paddle-wheels (which I described to him), readily drive a vessel against the current of those waters with so great a speed as to be highly beneficial. Mr. Jackson proves that he understood me well; for he has lately written letters, declaring, that about twenty-six years before their date, I described to him the principles of the steam-engine, which I have since put into operation to drive mills, which he has seen; and that I also explained to him my

plan for propelling boats by my steam-engine with paddle-wheels, describing the very kind of wheels now used for this purpose; and that I then declared to him my intention to apply my engine to this particular object, as soon as my pecuniary circumstances would permit.

"In the year 1800, or 1801, never having found a person willing to contribute to the expense, or even to encourage me to risk it myself; it occurred to me that, although I was then in full health, I might be suddenly carried off by the yellow fever that had so often visited our city (Philadelphia), or by some other disease of casualty, to which all are liable; and that I had not yet discharged my debt of honour to the state of Maryland, by producing the steam-waggons, I determined, therefore, to set to work the next day to construct one. I first waited upon Robert Patterson, Esq. professor of mathematics in the university of Pennsylvania, and explained to him my principles, as I also did to Mr. Charles Taylor, steam engineer, from England. They both declared these principles to be new to them, and highly worthy of a fair experiment; advising me without delay to prove them, in hopes that I might produce a more simple, cheap, and powerful steam-engine, than any in use. These gentlemen were the only persons who had such confidence, or afforded me such advice. I alo communicated my plans to B. H. Latrobe, Esq. at the same time, who publicly pronounced them chimerical, and attempted to demonstrate the absurdity of my principles, in his Report to the Philosophical Society of Pennsylvania, on steam engines; in which report he also attempts to shew the impossibility of making steam-boats useful, on account of the weight of the engine, and I was one of the persons alluded to as being seized with the steam-mania, in conceiving that waggons and boats could be propelled by steam-engines. The liberality of the members of the society caused them to reject that part of his report which he designed to be demonstrative of the absurdity of my principles; saying, they had no right to set up their opinions as a stumbling-block in the road of any exertions to make a discovery. They said I might produce something useful, and ordered it to be struck out. What a pity they did not also reject his demonstrations respecting steam-boats! for, notwithstanding them, they have run, are now running, and will run; so has my engine and all its principles succeeded; and so will land-carriages as soon as these principles are applied to them.

"In consequence of this determination above alluded to, I hired workmen and went to work to make a steam waggon, and had made considerable progress in the undertaking, when the thought struck me, that, as my steam engine was entirely different in form, as well as in its principles, from all others in use, I could obtain a patent for it and apply it to mills, more profitably than to waggons; for until now I apprehended that, as steam-mills had been used in England, I could only obtain a patent for waggons and boats. I stopped the work immediately, and discharged my hands, until I could arrange my engine for mills; having laid aside the steam waggon for a time of more leisure.

"Two weeks afterwards I commenced the construction of a small

engine, for a mill to grind plaister of Paris. The cylinder six inches in diameter, and the stroke of the piston eighteen inches, believing that, with one thousand dollars I could fully try the experiment. But before I had done with experiments, I found that I had expended three thousand seven hundred dollars—all that I could command! I had now to begin the world anew, at the age of forty-eight, with a large family to support. I had calculated that if I failed in my experiment, the credit I had acquired would be entirely lost, and, without money or credit, at my advanced age, with many heavy incumbrances, my way through life appeared dark and gloomy indeed! But I succeeded perfectly with my little engine, and preserved my credit. I could break and grind 300 bushels of plaister of Paris, or 12 tons, in twenty-four hours; and, to show its operation more fully to the public, I applied it to saw stone, in Market-street, where the driving of twelve saws in heavy frames, sawing at the rate of 100 ft. of marble in twelve hours, made a great show, and excited much attention. I thought this was sufficient to convince the thousands of spectators of the utility of my discovery; but I frequently heard them inquire if the power could be applied to saw timber, as well as stone, to grind grain, propel boats, &c.; and, though I answered in the affirmative, I found they still doubted. I therefore determined to apply my engine to many new uses, and to introduce it and them to the public notice.

"This experiment completely tested the correctness of my principles, agreeably to my most sanguine hopes. The power of my engine increased in a geometrical proportion, while the consumption of fuel had only an arithmetical ratio; and in such proportion that every time I added one fourth to the consumption of fuel, the power of the engine was doubled; and that twice the quantity of fuel required to drive one saw, would drive sixteen saws at least; for, when I drove two saws, the consumption was eight bushels of pit coal in twelve hours; but when twelve saws were driven, the consumption was not more than ten bushels; so that the more we resist the steam, the greater is the effect of the engine. On these principles very light but powerful engines can be made, suitable for propelling boats and land carriages, without the great incumbrance of their own weight, as mentioned in Mr. Latrobe's demonstrations. In the year 1804, I constructed at my works, situated a mile and a half from the water, by order of the Board of Health of the city of Philadelphia, a machine for cleansing docks. It consisted of a large flat or lighter, with a steam engine of the power of five horses on board, to work machinery to raise the mud into lighters. This was a fine opportunity to show the public that my engine could propel both land and water carriages, and I resolved to do it. When the work was finished, I put wheels under it, and though it was equal in weight to two hundred barrels of flour, and the wheels were fixed on wooden axletrees for this temporary purpose in a very rough manner, and attended with great friction of course; yet with this small engine, I transported my great burthen to the Schuylkill with ease; and when it was launched into the water, I fixed a paddle wheel at the stern,

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and drove it down the Schuylkill to the Delaware, and up the Delaware to the city; leaving all the vessels going up behind me, at least half way, the wind being a head.

"Some wise men undertook to ridicule my experiment of propelling this great weight on land, because the motion was too slow to be useful. I silenced them by answering, that I would make a carriage to be propelled by steam, for a bet of three hundred dollars, to run upon a level road against the swiftest horse they could produce. I was then as confident as I am now, that such a velocity could be given to carriages.

"Having no doubt of the great utility of steam carriages on turnpike roads, with proper arrangements for supplying them with water and fuel; and believing that all turnpike companies were deeply interested in carrying them into operation, because they would smooth and mend the roads instead of injuring them as the narrow wheels do; on the 26th of September, 1804, I submitted to the consideration of the Lancaster Turnpike Company, a statement of the cost and profits of a steam carriage, to carry one hundred barrels of flour, fifty miles in twenty-four hours; tending to show, that one such steam carriage would make more net profits than ten waggons drawn by five horses each, on a good turnpike road; and offering to build such a carriage at a very low price. My address closed as follows:—

"It is too much for an individual to put in operation every improvement which he may invent. 'I have no doubt but that my 'engines will propel boats against the current of the Mississippi, and 'carriages on turnpike roads with great profit; I now call upon those 'whose interest it is to carry this invention into effect.' In the year 1805, I published a work describing the principles of my steam engine, with directions for working it, when applied to propel boats against the current of the Mississippi and carriages on turnpike roads. And I am still willing to make a steam carriage that will run fifteen miles an hour on good level rail ways, on condition, that I have double price if it shall run with that velocity; and nothing at all for it if it shall not come up to that speed. What can an inventor do more, than to insure the performance of his inventions? Or, I will make the engine and apparatus at a fair price, and warrant its utility for the purpose of conveying heavy burthens on good turnpike roads. I feel it just to declare, that with Mr. Latrobe I myself believed, that with the ponderous and feeble steam engine now used in boats, they never could be made useful in competition with sailing boats, or to ascend the Mississippi; believing the current of that river to be more powerful than it is. But I rejoice, that with him I have been mistaken; for I have lived to see boats succeed well with those engines, and I still hope to see them so completely excelled and outrun by using my engine, as to induce the proprietors to exchange the old for the new more cheap and powerful engines.

"I have been highly delighted in reading a correspondence between John Stevens, Esq. and the Commissioners appointed by the legislature of New York, for fixing upon the site of the new canal, pro-

posed to be cut in that state. Mr. Stevens has taken a most comprehensive and very ingenious view of this important subject; and his plan of rail ways for the carriages to run upon, removes all the difficulties that remain to be overcome. I had the pleasure also of hearing gentlemen of the keenest penetration and of great mechanical and philosophical talents, freely give into the belief, that steam carriages will become very useful.

"Mr. John Ellicot (of John), proposed to make roads of substances, such as the best turnpike roads are made with, with a path for each wheel to run on, and having a railway on posts in the middle to guide the tongue of the waggon, and to prevent any other carriage from travelling upon it. Then, if the wheels were made broad and the paths smooth, there would be very little wear; such roads might be cheaply made, they would last a long time and require very little repair; and they ought to be preferred in the first instance to those proposed by Mr. Stevens; as two ways could be made in some parts of the country for the same expense as one could be made with wooden rails; but either of the modes would answer the purpose, and the carriages might travel by night as well as in the day. When we reflect upon the obstinate opposition that has constantly been made by a great majority, to every step to improvement, from bad roads to turnpike roads, from turnpike roads to canals, and from canals to rail ways for horse carriages; it is too much to expect, that the prodigious leap from bad roads to rail ways for steam carriages, will be made at once; one step in a generation is all that we can hope for. If the present generation shall adopt canals, the next may try the rail ways with horses, and the third generation may use the steam carriages.

"But why may not the present generation, who have already good turnpike roads, make the experiment of using steam carriages upon them? They will, assuredly, effect the movement of heavy burdens, with a slow motion of two and a half miles an hour; and, as their progress need not be interrupted, they may travel fifty or sixty miles in the twenty-four hours. This is all that I hope to see in my time; and though I never expect to be concerned in any business, requiring the regular transportation of heavy burdens on land; because, if I am connected in the affairs of a mill, it shall be driven by steam, and be placed on some navigable water, to save land carriage. Yet I certainly intend, as soon as I can make it convenient, to build a steam carriage, that will run on good turnpike roads, on my own account, if no other person will engage in it; and I verily believe that the time will come when carriages, propelled by steam, will be in general use, as well for the transportation of passengers as goods; travelling at the rate of 15 miles an hour, or 300 miles a day!

"It appears necessary to give the reader some idea of the principles of the steam engine which is to produce such new and singular effects; and this I will endeavour to do in as few words as I can, by showing the extent to which the principles are already applied.

"To make steam as irresistible or powerful as gunpowder, we have only to confine it, and to increase the heat by adding fuel to the

boiler. A steam engine, with a working cylinder, only nine inches in diameter, and the stroke of the piston three feet, will exert a power sufficient to lift from 3000 to 10,000 lbs. perpendicularly, two and a half miles per hour. This power, applied to propel a carriage on level roads or railways, would drive a very great weight with much velocity, before the friction upon the axletrees, or the resistance of the atmosphere, would balance it.

" This is not speculative theory. The principles are now in practice, driving a saw-mill, at Manchacks, on the Mississippi; two at Natchez, one of which is capable of sawing 5000 feet of boards in twelve hours; a mill at Pittsburgh, able to grind twenty bushels of grain per hour; one at Marrietta, of equal power; one at Lexington, (Kentucky,) of the same power; one a paper-mill, of the same power; one of one-fourth the power, at Pittsburgh; one at the same place of three and a half times the power, for a forge, and for rolling and slitting iron; one of the power of 24 horses, at Middletown, (Connecticut,) driving machinery of a cloth manufactory; two at Philadelphia, of the power of five or six horses; and many making for different purposes; the principles applying to all cases where power is wanted to drive machinery."

Mr. Evans at the same time describes his own steam engine, which is well known to be in very general use in America.

A the boiler, B the working cylinder, C the lever beam, D the fly wheel, E the cistern or condenser, F the cold water pump, G the supply pump, H the fire place, I the chimney flue, K the safety valve, which may be loaded with from 100 to 150 lbs. to the inch area; it will never need more, and it must never be fastened down.

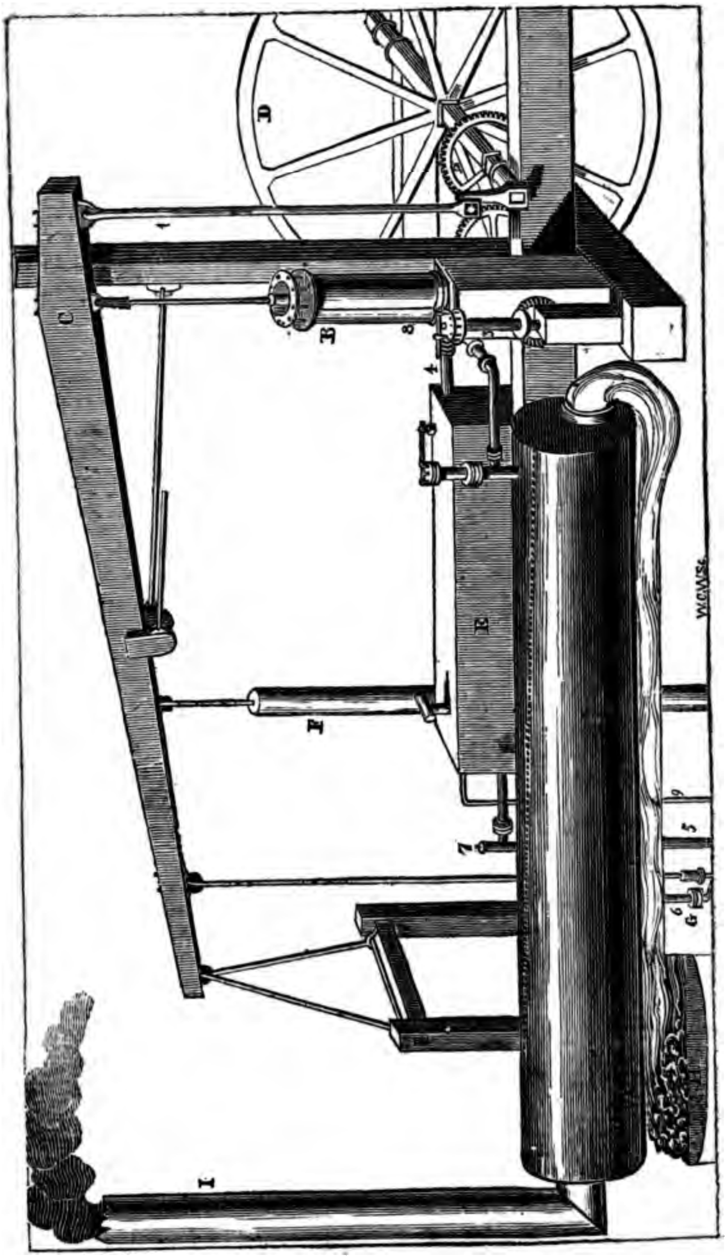
The boiler being filled with pure water (rain or distilled water) as high as the dotted line, and the fire applied, the smoke enters the centre flue, which passes through the centre of the water to ascend the flue I, and thus acts on a large surface.

When the steam lifts the safety valve, it is let into the cylinder by opening the throttle valve, and drives the piston up and down, which, by the rod 1, gives motion to the fly wheel; and the wheel 2 gives motion to a shaft, passing through the supports of the cylinder to turn the spindle of the rotary-valves, 3, 8, which lets the steam both into and out of the cylinder, at the proper time.

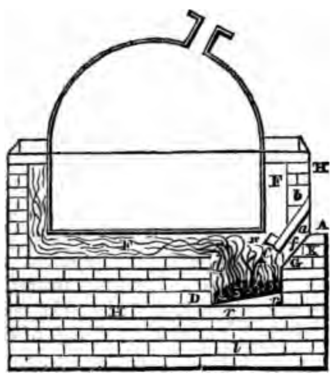
The steam, escaping by the pipe 4, curved backwards and forwards in a zigzag form, and immersed in the water in the cistern E, (which is supplied by the cold water pump F,) is condensed; and the distilled water formed thereby descends, by the pipe 5, into the supply pump G, and is forced into the boiler again by the pipe 6.

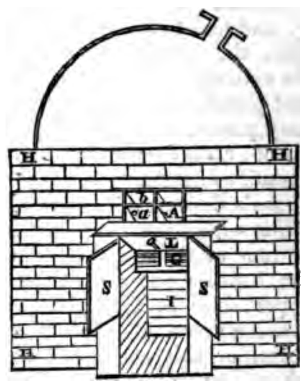
But as boiling disengages air from the water, so the shifting-valve, 7, is necessary. This valve lifts at every puff of the steam, and a small quantity escapes; and it shuts, and a vacuum is instantly formed, as the crank passes the dead points.

The small waste of water may be replaced by condensing water in the cistern E, and causing it to run down the pipe G, through a hole in the key of a stop-cock one-32nd part of an inch in diameter; a small hole, indeed, to supply a boiler of a steam engine of twenty horses power.



and consequently a greater degree of heat taking place, and the smoke and fresh air uniting in the great heat, the smoke is inflamed, and rendered useful in adding to the heat of the furnace; besides, this portion of fresh air is so conducted as to act partly on the kindling or kindled fuel, and raising it to a greater degree of heat after it has served its purpose, by uniting with and inflaming the smoke; and therefore is employed, in some measure, usefully, even after the coal has ceased to smoke: secondly, to the above may be added, the frame of the furnace, which is so constructed that the full-kindled fuel is kept backward in the furnace, while the fresh coal lies before, and is more gradually kindled than if introduced further among the full-kindled fuel, while the heat of the furnace is little injured or damped by the introduction of fresh coal, as is more fully described afterwards.





"The coal is admitted into the furnace by a hopper, feeder, or mouth-piece A, made of cast iron, but which may be made of other materials, and inclined to the horizon; so that the coal in it may, in some measure, fall into the fire place above the bars, as the fuel is spent; in the upper part of this hopper, feeder, or mouth-piece, is a plate *a*, placed at a small distance, or from about three-eighths to three-fourths of an inch from the upper side of the hopper, betwixt which plate and the upper plate, or side of the hopper, a stream of air rushes downward on the fire, at about half a right angle to the horizon, which stream of air assists in consuming the smoke, as before mentioned, and more fully described hereafter. B is a section of the bars, which are, in general, a little inclined to the horizon, as in the figure, that the fuel may more easily fall, or be pushed backwards in the furnace; at *c* is an opening above the bars, and below the lower end of the hopper, which is in general fitted with a grated door or doors, which open for the more convenient cleansing of the furnace, and the grated form of the doors is also designed for admitting air into the fuel, as well as

at the bars, consequently the air is more concentrated in the middle of the burning fuel, produces a greater heat than if admitted only betwixt the bars; this grated form of the doors is very convenient for the admission of a poker or instrument for pushing backward the kindled fuel, while the fresh coal, or that which is not so well kindled, falls down to supply its place. In some others of these furnaces, the opening below the lower end of the hopper, and above the fore end of the bars, is left without doors at all; at this opening it is convenient, when the fire is mended, to push the coal from the fore side backward, as mentioned above, or it may be pushed backward with a hooked poker, P, by applying the hooked part of it through the furnace bars below; by either of which means the kindled coals are put backwards, while the fresh coal, or that which is not so well kindled, falls down to supply their place; that is, the coals in the situation *c*, are pushed towards *d*, while those in the situation *f* fall down to supply the place of those which were driven from *c* towards *d*; by such means the strength or heat of the fire is not much damped by the introduction of fresh coal, and the coals which have fallen from *f* towards *c* are not so rapidly kindled as if introduced above the burning fuel; at the same time the smoke, which arises from these newly-introduced coals, passes partly through the full kindled coal and partly over, and in contact with the great heat of the burning fuel, and, meeting at the same time with the current of fresh air coming downwards, and tending also to drive the smoke still nearer to the bright kindled fuel, does, in general, completely inflame the smoke, and render it useful in adding to the heat of the furnace.

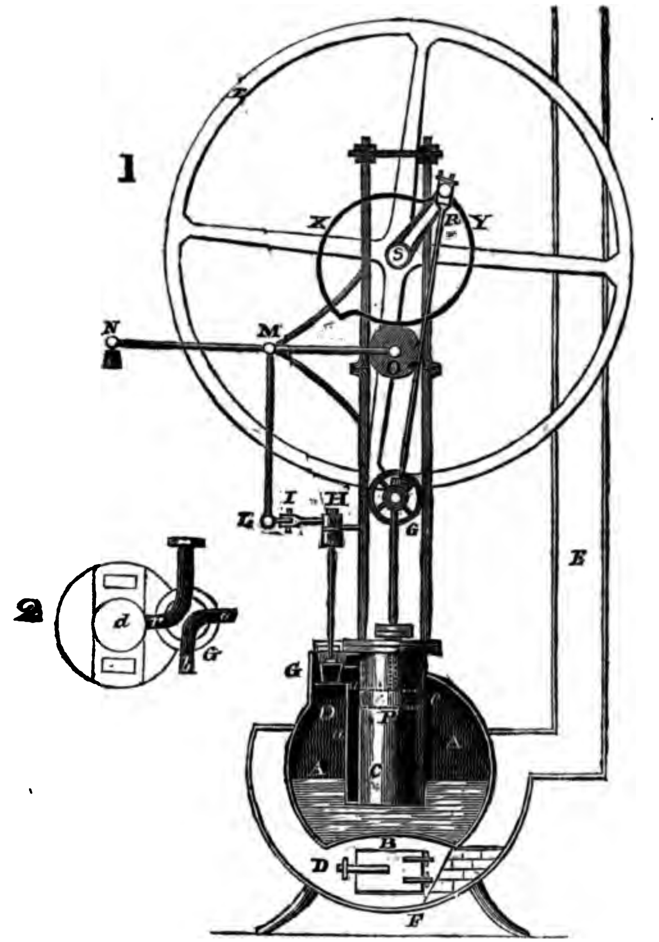
Another end obtained by the stream of fresh air, is to keep in some measure the great heat of the furnace from acting so violently on that part of the hopper which is nearest it and mostly exposed to its heat, and liable to be damaged thereby, which it does by the continual current of fresh cool air that is in contact with those parts. The construction of the furnace may be much varied, but the chief improvements are, that the fuel in combustion is supplied with air by the foreside as well as by the bars; the hopper is placed in such a situation that the kindled or unkindled coal may in part fall to the foreside of the furnace above the bars, as the other fuel is pushed backward in the furnace, and the admission of fresh air to pass over the burning fuel by means of a definite space or spaces, opening or openings, made for that purpose; so that this stream, current, or currents of air, partly come in contact with the burning fuel itself, forcing also the smoke with more immediate union with the burning fuel and great heat of the furnace. The success of the furnace depends also in a considerable degree upon what is called the draught of the furnace; that is, the chimney and flues are so constructed, that a sufficient current of air may pass through the fire to bring it to a proper degree of heat; also, that the current of fresh air may have such force as to come pretty much in contact with the burning fuel, and to convey the smoke along with it through the hottest of the flame: if this is not the case, the smoke will not be so completely consumed in these furnaces. The hopper is allowed to be kept as

full of coals as possible, and either wholly or in part small coal, so as to prevent air as much as possible getting in by that passage; this must be attended to when the furnace is in its ordinary working state: yet, sometimes it is necessary to keep this opening of the hopper, either wholly, or in part open, when there is little heat wanted.

The utility of this scheme was sufficiently proved by the very general adoption which followed its publication. The combustion of smoke being now established as not only practicable, but economical, it being a fact, that all the smoke discharged from a chimney is but so much good fuel which wanted only the proper application of air to render it useful. It is equally true that the flame which is frequently at the top of furnace chimneys has no existence but there; while ascending the flue it is merely dense smoke, consisting of azote of the atmospheric air, decomposed in passing through the fire; of hydrogen, coal-tar, and carbonaceous matter, of such a high temperature that it only wants oxygen to make it inflame spontaneously: this it obtains from the atmospheric air, into which it ascends, and then presents such appearances as would make a hasty observer adopt the opinion, that the flame had ascended as flame from the fuel in the furnace, which is by no means the case.

Messrs. Trevithick and Vivian's High-Pressure Engine (patented 1802) has been found the most compact, simple, and effective engine, perhaps, ever known. In an early part of this work reasons are given for the superiority of high-pressure over condensing engines, and we shall only now say that Messrs. Trevithick and Vivian's engine has, of all others on this principle, obtained the highest reputation.

"A (Fig. 1) represents the boiler made of a round figure, to bear the expansive action of strong steam. The boiler is fixed in a case, D, luted inside with fire clay, the lower part of which constitutes the fire-place, B, and the upper cavity affords a space round the boiler, in which the flame or heated vapour circulates till it comes to the chimney, E. The case, D, and the chimney are fixed upon a platform, F, the case being supported upon four legs; C represents the cylinder, inclosed for the most part in the boiler, having its nozzle, steam-pipe, and bottom, cast all in one piece, in order to resist the strong steam, and with the sockets in which the iron uprights of the external frame are firmly fixed. G represents a cock for conducting the steam, as may be more clearly seen by observing Fig. 2, which is a plan of the top of the cylinder. *b*, Figs. 1 and 2, represents the passage from the boiler to the cock, G; this passage has a throttle valve, or shut, adjustable by a handle, so as to wiredraw the steam, and suffer the supply to be quicker or slower. The position of the cock is such, that the communication from the boiler, through *b*, by a channel in the cock, is made good to *d*, which denotes the upper space of the cylinder above the piston, at the same time that the steam pipe, *a*, (more fully represented in Fig. 1) is made to afford a passage from the lower space in the cylinder beneath the piston to the channel, C, through which the steam may escape into the outer air, or be directed or applied to heating fluids, or other useful purposes. It

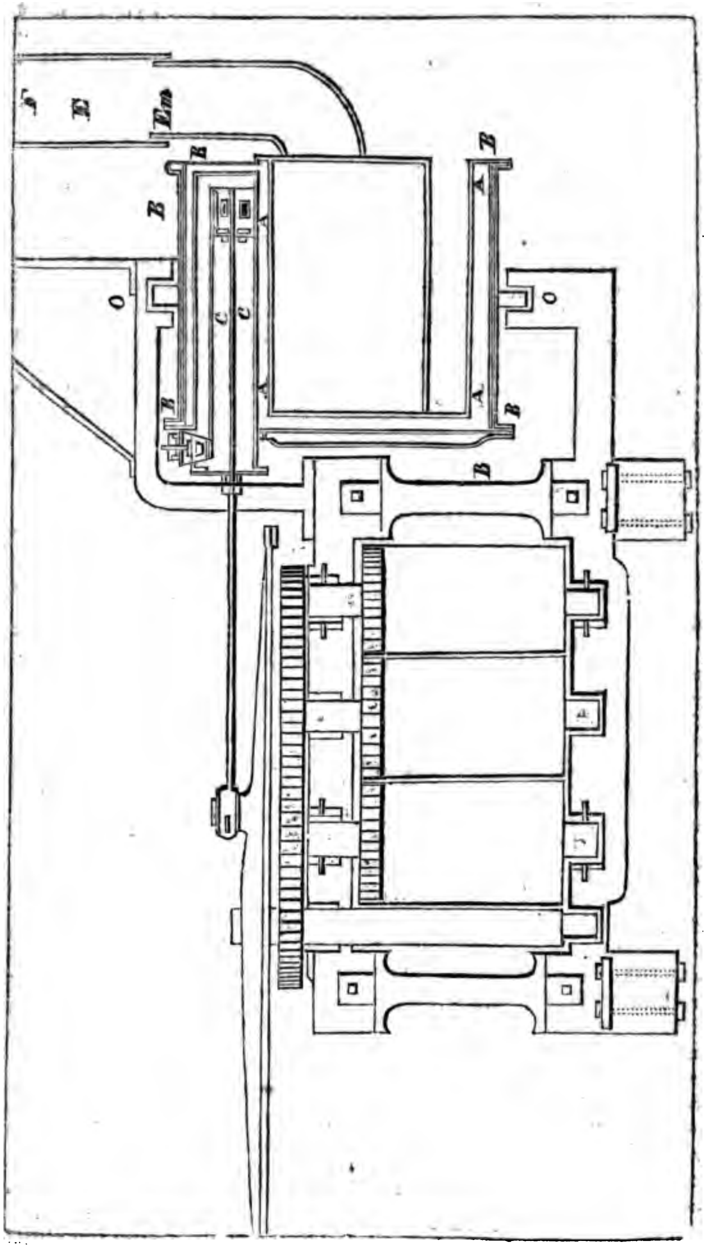


will be obvious that, if the cock be turned one quarter of a turn in either direction, it will make a communication from the boiler passage, *b*, to the lower part of the cylinder by or through *a*, at the same time that the passage, *r*, from the upper part of the cylinder, will communicate with C, the passage for conveying off the steam. P Q is a piston-rod moving between guides, and driving the crank, R S; by means of the rod, Q R, the axis of which crank carries the fly, T, and is the first mover to be applied to drive machinery at S. X Y is a double snail, which in its rotation passes down the small wheel O, and raises the weight, N, by a motion in the joint, M, of the lever, O N, from which downwards proceeds an arm, M L, and con-

sequently the extremity, L, is at the same time urged outwards. This action draws the horizontal bar, L I, and carries the lever or handle, H I, which moves upon the axis of the cock, G, through one-fourth of a circle. It must be understood that H I is fore-shortened, (the extremity, I, being more remote from the observer than the extremity, H,) and also there is a clack or ratchet wheel on the part, H, which gathers up during the time that L is passing outwards, and does not then move the cock, G, but that, when the part X, of the snail opposite O, that is to say, when the piston is about the top of its stroke, then the wheel, O, suddenly falls into the concavity of the snail; and the extremity of L, by its return at once, pushes I H through the quarter circle, and carries with it the cock, G, and turns the steam upon the top of the piston, and also affords a passage for the steam to escape from beneath the piston. Every stroke, whether up or down, produces this effect by the half turn of the snail, and reverses the steam ways, as before described; or the cock may be turned by various well-known methods, such as the plug with pins or clamps striking on a lever in the usual way, and the effect will be the same, whether the quarter turns be made backward or forward, or by a direct circular motion, as is produced by the machinery here represented; but the wear of the cock will be more uniform and regular if the turns be all made in the same way."

The same specification likewise describes a very simple and ingenious method of giving motion to the fly wheel, by making the piston-rod of an inflexible bar, and connecting it at once with the crank. The cylinder and boiler are allowed to vibrate on pivots, and thereby follow the revolving of the crank. The drawing here given represents also the outline of a machine for rolling sugar canes, thereby showing at once the connection of the engine with the machinery of the mill.

"The working cylinder, C, with its piston, steam pipe, nozzle and cock, are inserted in the boiler, as here delineated. The piston rod drives the fly, upon the arbor of which is fixed a small wheel which drives a great wheel upon the axis; the guides are rendered unnecessary in this application of the steam engine, because the piston-rod is capable, by an horizontal vibratory motion of the whole engine upon its pivots, O, to adapt itself to all the required positions, and while the lower portions of the chimney partakes of this vibratory motion, the upper tube, E F, is enabled to follow it by its play upon the two centres or pivots in the ring above. In such cases or constructions, as may render it more desirable to fix the boiler with its chimney and other apparatus, and to place the cylinder out of the boiler, the cylinder itself may be suspended for the same purpose upon trunnions or pivots in the same manner, one or both may be perforated, so as to admit the introduction and escape of the steam or its condensation. And in such cases where it may be found necessary, to allow of no vibratory motion of the boiler or cylinder, the same may be fixed, and guides be used. The manner in which the cock is turned is not represented in the two drawings, but every competent workman will, without difficulty, understand how the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C
C

stroke of pins duly placed in the circumference of the fly, and made to act upon a cross fixed on the axis of the cock, or otherwise, will produce the motion. The steam which escapes in this engine is made to circulate in the case round the boiler, where it prevents the external atmosphere from affecting the temperature of the included water, and affords by its partial condensation a supply for the boiler itself, and is or may be afterwards directed to useful purposes."

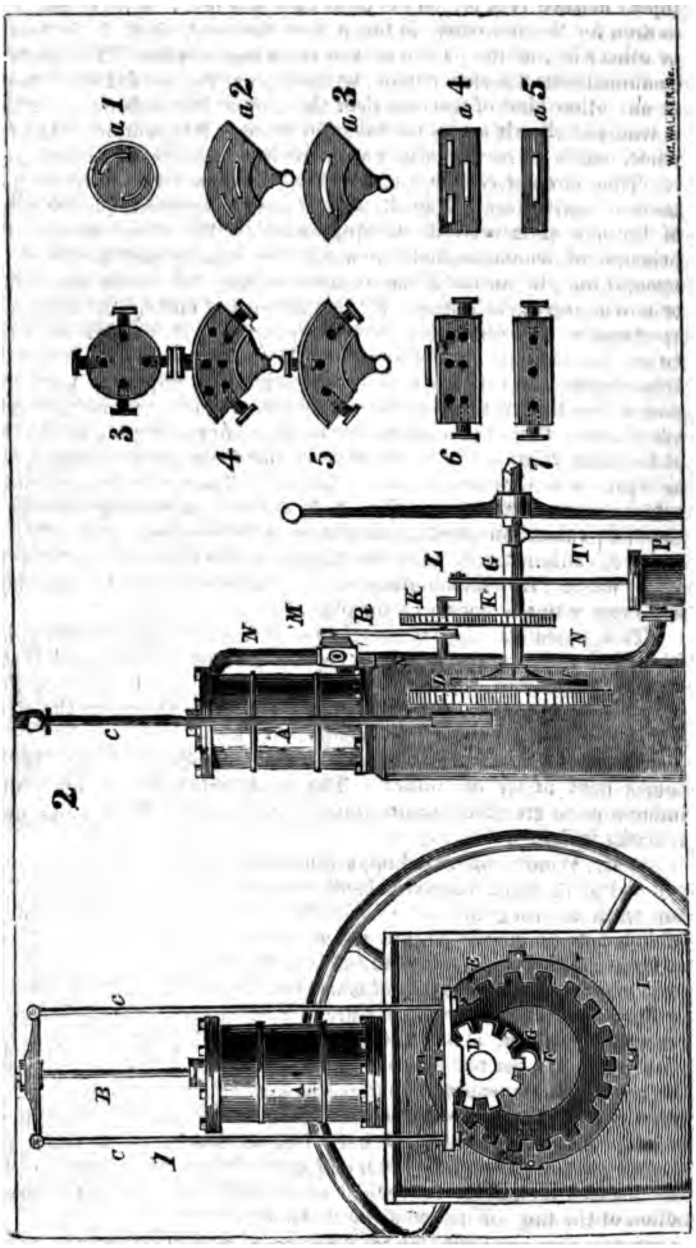
This latter plan, namely, the vibrating cylinder, looks well in theory, but we fear in practice it would be found very imperfect. Reciprocation, as we have shown, is a great destroyer of power, and here the whole engine boiler, water, cylinder, fire grate, and all the apparatus, are constantly moving backwards and forwards, and all this, too, merely to *dispense with the guide wheel and connecting rod.*

Messrs. Trevithick and Vivian propose in the same specification to use their engine for the purpose of travelling on the common road. The carriage resembles in form the common stage coach; an iron frame, containing the boiler and cylinder, is placed behind the carriage; the cylinder is likewise horizontal. Our readers will readily see the application of the preceding apparatus to the wheels by a cranked axle. On both ends of the axle cog wheels are fixed, by which means, when the axle is made to revolve, it communicates its motion to the hinder and larger wheels of the carriage. The machine has a fly wheel, to preserve the regularity of the motion: means are also provided for throwing any of the wheels out of gear, by which a turn can be made without difficulty.

It appears that, in the year 1804, Mr. Trevithick had an opportunity of proving the utility of his Locomotive Engine upon the Merthyr Tydvil Rail-road, South Wales. The engine had a cylinder of 8 inches diameter, and a stroke of 4 ft. 6 in. in length, and drew after it upon the rail-road as many carriages as carried ten tons of bar iron, from a distance of nine miles, which it performed without any supply of water to that contained in the boiler at the time of setting out; travelling at the rate of five miles an hour.

Mr. Matthew Murray, of Leeds, obtained a patent for a Portable Engine, in 1802, which displays much novelty and ingenuity.

"Figs. 1 and 2 represent front and side views of the combination of parts of this engine. A the steam cylinder; B the piston rod; C C, connecting-rods, for connecting the piston rod to the pin in the wheel D; E a wheel, fixed to the side of the cistern, I I I I, with the teeth inwards, to admit the teeth of the wheel, D, for the purpose of giving a parallel direction to the rods, C C; F a plain wheel, upon the fly-wheel shaft, G; the wheel, F, is furnished with a double conical centre for the wheel, D, to run upon; I I I I is a cistern or frame of plates, on and in which the whole combination of materials constituting this engine is fixed; K K two wheels, one upon the fly-wheel shaft, G, the other upon the crank shaft, L; these wheels and crank are for the purpose of working the lever, R, in Fig. 2, which lever gives immediate motion to the air-pump, P, and the cold and hot water pump; T is an iron bar for supporting the shaft; M is a slide valve for opening and shutting the communication of the steam


1
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6
7
a 1
a 2
a 3
a 4
a 5
B
M
N
R
K
L
G
T
W.G. WALKER, Sc.

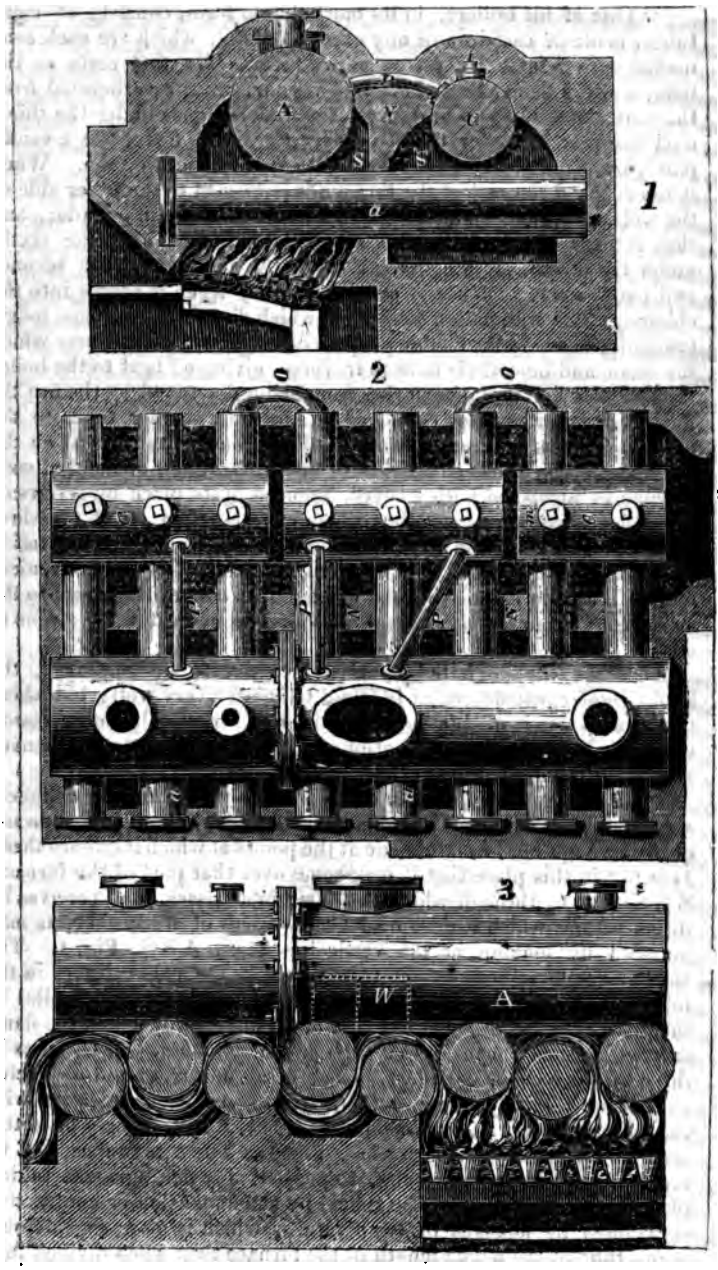
pipes, marked N N N, and is described in Figs. 3, 4, 5, 6, and 7; a motion for the slide valve is taken from the crank shaft, L, by levers, or otherwise, as the nature of the valve may require. The parts so combined form a perfect engine, without requiring any fixture of wood, or any other kind of framing than the ground it stands upon, which is transferable without being taken in pieces, (the motion of the fly-wheel shaft giving circular power to any process or manufactory requiring circular motion,) or irrigating land, or for the various purposes of agriculture. Figs. 3, 4, 5, 6 and 7, represent various forms of the new slide-valve in its application to the steam-engine; the principle of which consists in moving in a circle part of a circle or straight line, by means of flat surfaces or faces (or nearly so) sliding or moving upon each other, for the purpose of uniting the necessary apertures in the steam pipes or cylinders. Fig. 3 is a view of a circular flat sliding valve; the dotted lines show the avenues to the steam pipes. *a* 1 is a figure representing the upper or moveable part of the slide valve, Fig. 3, where the conducting or uniting cells are formed: there is a circular spring for compressing *a* 1 to the face of the slide valve in Fig. 3, so as to render them perfectly steam and air tight, which perfection they will naturally acquire by constantly rubbing upon each other. Figs. 4, 5, 6 and 7, show four varieties of the slide valve, for working double or single powers. *a* 2, *a* 3, *a* 4, and *a* 5, contain the cells for conducting to the different apertures or steam ways. Any further description is unnecessary, as the drawings will convey to any one the principles of these inventions."*

This ingenious apparatus, though possessing much merit, infringed, it appears, on the patent right of Messrs. Boulton and Watt, and the patent was, therefore, repealed in 1803. An engine on this plan has been at work many years at St. Peter's Quay, on the river Tyne, and is found to answer uncommonly well.

Mr. Woolf's very excellent and ingenious boiler (patented 1803) comes next under our notice. The great utility of this apparatus induces us to give the specification, together with Mr. Woolf's own remarks in full.

" Mr. Woolf's improved apparatus consists, first, of two or more cylindrical vessels properly connected together, and so disposed as to constitute a strong and fit receptacle for water, or any other fluid intended to be converted into steam, whether at the usual heats, or at temperatures and under pressures uncommonly high; and also to present an extensive portion of convex surface to the current of flame or heated air or vapour from a fire. Secondly, of other cylindrical receptacles placed above these cylinders, and properly connected with them, for the purpose of containing water and steam, and for the reception, transmission, and useful application of the steam generated from the heated water or other fluid. And, Thirdly, of a furnace so adapted to the cylindrical parts just mentioned, as to cause the greater part of the surface of all and each of them, or as much of the said surface as may be convenient or desirable, to receive the direct action of the fire, or heated air and vapour.

* Specification of Patent.


1
2
B
3
W
A

"One of his boilers, in its most simple form, consists of eight tubes, made of cast-iron or any other fit metal, which are each connected with a cylinder placed above them. The fuel rests on the bars, and the flame, heated air, and vapour, being reverberated from the part above the two first smaller cylinders, goes under the third, over the fourth, under the fifth, over the sixth, under the seventh, partly over and partly under the eighth small cylindric tube. When it has reached the end of the furnace it is carried to the other side of the wall, built under and in the direction of the main cylinder, and then returns under the seventh smaller cylinder, over the sixth, under the fifth, over the fourth, under the third, over the second, and partly over, and partly under the first; when it passes into the chimney. The wall before mentioned which divides the furnace longitudinally, answers the double purpose of lengthening the course which the flame and heated air have to traverse, giving off heat to the boiler in their passage, and of securing from being destroyed by the fire the flanges or other joinings employed to unite the smaller tubes to the main cylinder. The ends of the smaller cylindric tubes rest on the brick work which forms the sides of the furnace, and one end of each of them is furnished with a cover, secured in its place by screws or any other adequate means, but which can be taken off at pleasure, to allow the tubes to be freed from time to time from any incrustation or sediment which may be deposited in them. To any convenient part of the main cylinder a tube is affixed, to convey the steam to the steam engine, or to any vessel intended to be heated by means of steam.

"When very high temperatures are not to be employed, the kind of boiler just described is found to answer very well; but where the utmost force of the fire is desirable, Mr. Woolf, for a reason which shall be afterwards mentioned, combines the parts in a manner somewhat different, though the same in principle.

"In Fig. 2, A is the main cylinder crossing the smaller cylinders *a a a*, half way between their middles and ends, but not joined to any of them excepting the middle one at the points at which it crosses them. It is put in this place that it may come over that part of the furnace, S S S, Fig. 1, through which the flame first passes, and receives its direct action, which it does over nearly a half of its surface, as may be seen by looking at the vertical section, A S S, Fig. 1. The smaller cylinders have a communication with the main cylinder in the following manner:—Three cylinders, C C C, are placed parallel to the main cylinder, A, over the part of the furnace by which the flame returns, in such a manner that each of the cylinders, C C C, takes in three of the smaller cylinders, *a a a*, being united to and connected with them. The cylinders, C C C, have a direct communication with the main cylinder, A, by the pipes or tubes, P P P, as may be better seen by the cross vertical section, Fig. 1. The three tubes, C C C, are preferred to one long tube, to prevent any derangement taking place in the furnace or in the tubes, by the expansion or contraction occasioned by changes of temperature, which is more considerable in one tube of the whole length of the furnace than when divided into

three portions; and it is for the same reason that the tube A is not made to communicate directly with the smaller tubes, *a a a*, but mediately by means of the tubes marked C and P.—N. B. The two outermost of the tubes marked P, instead of going parallel to the middle tube, P, may be both inclined towards it, so as to join the cylinder A near the middle; or any other direction may be given to them, to prevent derangement by expansion.

"The tubes C and *a* are kept from separating by bolts from the inside of *a* passing through the top of C, where they are secured by nuts screwed on to them, (*see* Fig. 3); and these parts of C are so contrived, that by taking off any of the nuts a cover may be removed, and a hole presented large enough to admit a man's hand into C to clean it out.

"Fig. 3 is a longitudinal vertical section of the furnace, through the centre, showing the course which the flame and heated air are forced to take. The first three small cylinders are completely surrounded with flame, being directly over the fire: the flame is stopped by the brick-work, W, over the fifth, and forced to pass under it, and then over the sixth, where it again meets with an interruption, which forces it to go under the seventh, and over the eighth; it then turns round the end of the longitudinal wall which divides the furnace, and passes over the eighth smaller cylinder, under the seventh, and so on, alternately, over and under the other tubes, till it reaches the chimney. The wall that divides the furnace may be seen in Fig. 2.

"To secure a free communication between the different parts of the boiler, the three tubes of the middle cylinder, C, are connected with those of the two exterior C's by two pipes, *o o*. The other ends of the tubes, *a a a*, are each fitted with a cover properly secured and bolted, but which can be taken off occasionally to clean out the boiler.

"In working with such boilers the water carried off by evaporation is replaced by water forced in by the usual means; and the steam generated is carried to the place intended by means of tubes connected with the upper part of the cylinder A.

"It may not be improper," says Mr. Woolf, "to call the attention of those who may hereafter wish to construct such apparatus to one circumstance, namely, that in every case the tubes composing the boiler should be so combined and arranged, and the furnace so constructed, as to make the fire, the flame and heated air, to act around, over, and among the tubes, embracing the largest possible quantity of their surface. It must be obvious to any one that the tubes may be made of any kind of metal; but I prefer cast-iron as the most convenient. The size of the tubes may be varied: but in every case care should be taken not to make their diameter too great; and it must be remembered that the larger the diameter of any single tube in such a boiler the stronger it must be made in proportion, to enable it to bear the same expansive force as the smaller cylinders. It is not essential, however, to my invention that the tubes should be of different sizes; but I prefer that the upper cylinders, especially the one which I call the main cylinder, should be larger than the lower ones, it being the reservoir, as it were, into which the lower ones

send the steam, to be thence conveyed away by the steam pipe or pipes. The following general direction may be given respecting the quantity of water to be kept in a boiler in my construction: it ought always to fill not only the lower tubes but the main cylinder, A, and the cylinder, C, to about half their diameter, that is, as high as the fire is allowed to reach, and in no case ought it to be allowed to get so low as not to keep full the necks or branches which join the smaller cylinders, marked with the letter *a*, to the cylinders A or C; for the fire is only beneficially employed when applied, through the medium of the interposed metal, to water, to convert it into steam: that is, the purpose of my boiler would, in some measure, be defeated, if any of the parts of the tubes exposed to the direct action of the fire should present in their interior a surface of steam instead of water, to receive the transmitted heat which must, more or less, be the case if the lower tubes, and even a part of the upper, be not kept filled with the liquid.

"As to the construction of the furnaces, though that must be obvious from the drawings, it may not be improper here to remark, that they should always be so built as to give a long and waving course to the flame and heated air, or vapour, forcing them the more effectually to strike against the sides of the tubes which compose the boiler, and so to give out a large portion of their heat before they reach the chimney: unless this be attended to, there will be a much greater waste of fuel than necessary; and the heat, communicated to the contents of the boiler, will be less from a given quantity of fuel.

"My invention is not only applicable to all the uses to which the boilers in common use are generally applied, but to all of them with much better effects than the latter, and can, besides, be applied to purposes in which boilers, constructed as they have hitherto been, would be of little or no use. The working of all kinds of steam engines is one important application of my invention; for the steam may be raised, in a boiler constructed in the manner before described, to such a temperature, and consequently to such an expansive force, as to work an engine even without condensing the steam, by simply allowing it to escape into the atmosphere after it has done its office, as proposed by Mr. James Watt, in the specification of his patent, dated January 5, 1769, whence, he says, engines may be worked by the force of steam only, by discharging the steam into the open air. In all cases where it is desirable to heat or boil water, or other fluids and substances, without the direct application of fire to the vessel or vessels containing them, which in such cases become secondary boilers, the use of my apparatus will produce superior to any obtained by any other means, no more being necessary than to make the vessels, or secondary boiler, containing the water or other fluids, and the substances immersed or dissolved in, or blended or mixed with the water or other fluids, to communicate by means of a tube or tubes, with the prime boiler, constructed in the manner before described. In such cases as in making extracts of every kind for the various purposes of arts and manufactures, and for the simple boiling of water or watery fluids, the steam should go directly into the vessel or secondary boiler, whose contents are to be heated or boiled; and the orifice or orifices

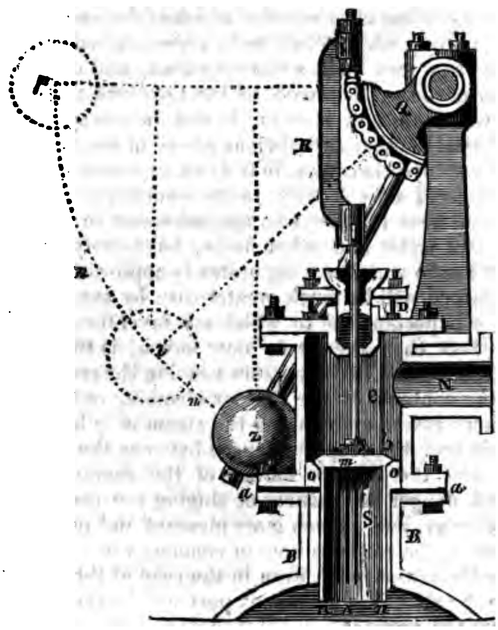
of the pipe or pipes through which the steam is conveyed should go to a considerable depth in the fluid, that the steam may be better able to give off its heat, and be condensed before it can reach the surface; and in every such case an allowance should be made for the increase which will be made to the quantity of liquid in the vessel to be heated, by the quantity of steam which will be condensed in the same before the process be ended. The vessels into which the steam is thrown may be either open or close, as the nature of circumstances may require: but where extracts are to be made from vegetable or other matters from which extracts are or may be made, as from hops, bark, drugs, and dry stuffs, for brewing, tanning, dyeing, and other processes, the materials will be much more completely exhausted of all their valuable parts; and in many instances they will be completely dissolved by employing close vessels, which in that case must be made very strong, a thing not difficult to be accomplished, when it is recollected that they may be at a distance from, and consequently out of the power of being deranged by the fire; and that they may be surrounded with, and, as it were, buried in massy stone or brick work, in addition to other and obvious means of securing them. My apparatus so employed becomes, in fact, an improved Papin's digester on a large scale. I do not wish to be understood as claiming the merit of having been the first who applied steam in the manner just described to boil water and other fluids, but merely as pointing out an important use to which my apparatus is applicable, and in which the effect obtained will be much greater than by any other means.

"Another important use to which my invention can be applied with better effect than the means now in use, is that of distillation on the large scale, and that by either sending the steam directly into and among the contents of the still or alembic, or by enclosing the still in another vessel, and making the steam of a high temperature to circulate in and to occupy the space between the exterior surface of the still and the interior surface of the containing vessel. In either case all danger of burning or singing the materials operated upon is done away, and a much more pleasant and pure spirit will be obtained than by the methods now in common use. I need not stop here to show the reason why, even in the case of throwing the steam directly into the still, the spirituous part will be the first to rise and pass over into the receiver.

"I might mention many other useful applications that may be made of my invention; but I shall only state one more, namely, to the drying of gunpowder, and lessening the danger of explosions in the manufacture of that article. By means of my invention any desired temperature, necessary for that purpose, may be produced where the powder is to be dried, without the necessity of having fire in, or so near the place, as to endanger its safety; for by employing steam only, conveyed through pipes and properly applied and directed without allowing any of it to escape into the room or apartment where the powder is, any competent workman can produce a heat equal to that found necessary for drying gunpowder, or much higher if required. Nor is the lessening of the danger of explosions the

only advantage which this way of drying gunpowder holds out, it presents another and an essential one for the goodness of the article, the heat can be completely regulated, so as to prevent, or at least lessen, the partial decomposition of the powder by the sublimation of the sulphur, which is found to take place by the methods at present in use."

We have had frequent opportunities of inspecting this excellent apparatus, and can, therefore, speak with confidence of its utility. One engine of Mr. Woolf's is now used with such a boiler to drive a saw mill, by Mr. Smart, of Lambeth Marsh, and is principally kept going by the saw-dust from the mill. Two safety valves are generally used, the plan of which is ingenious.



A is a part of the main cylinder of one of Mr. Woolf's boilers; B B the neck or outlet for the steam surmounted by the steam box C, which is joined to the neck B B by the flanges A A. The top or cover of the steam box C, marked with the letter D, which is well secured in its place, has a hole through it for the rod of the valve, so contrived as to answer the purpose of a stuffing box to make the rod work up and down steam tight, the stuffing being kept in its place by the usual means, as shewn in the section. By means of a pin or nail *b*, and the two vertical pieces *e e*, the piston rod is made fast to *m*, which is a cover of and joined to the hollow cylinder *n n*. The cover *m* fits steam tight into the collar *o o*, which is made fast to the flanges *a a*. The cylinder *n n* is open at the bottom,

having a free communication with the main cylinder A, and has three vertical slits, one of which, S, is shewn in the diagram. The sum of the surface of all these slits or openings is equal to the area of the opening of the collar *o o*, in which the cylinders *n n* works. When the steam acquires a sufficient degree of elastic force to raise the valve (that is, the cylinder *n n* with its cover *m*, and the rod R,) and whatever weight it may be loaded with, then the openings S, getting above the steam tight collar *o o*, allows the steam to pass into the steam box C. The quantity of steam that passes is proportioned to the elastic force it has acquired, and the weight with which the valve is loaded; and the rise of the openings S above the collar *o o*, will be in the same proportion. This valve may be loaded in any of the usual methods; but Mr. Woolf prefers the one shewn in the drawing, in which the upper part of the rod R is joined by means of a chain to a quadrant of a circle Q with an arm projecting from it, as represented in the plate, and which carries a weight Z, that may be moved near to or further from the centre of the quadrant, according as the pressure of the valve is wished to be increased or diminished. As the valve rises, the weight moves upwards in the arch *n n*, giving an increased resistance to the further rising of the valve, proportioned to the greater horizontal distance from the centre of Q, which the weight attains by its slide in the said arch, the said distance being measured in the line O P passing through the centre of the weight. Thus, if the weight Z press with a force equal to twenty pounds on the square inch of the aperture in O O in its present position, it will, when it rises to the position *i*, press with a force equal to thirty pounds, and at P, with a force equal to forty pounds on the square inch, so that the rod Q Z may be made to serve at the same time as an index to the person who attends the fire, nothing more being necessary for this purpose than to graduate the arch described by the end of the rod Q Z. In the side of the steam box C there is an opening N to allow the steam to pass from it by a pipe or tube to the steam engine, or to any secondary boiler, or for the purpose of conveying and applying it to any other vessel or use to which steam is applicable.

Hornblower's second Rotative Engine differs materially from his former one, it consists of

" A vessel in which the steam operates, made of cast-iron, extremely resembling a globe, flatted at the poles, (see Fig. 1) which shows one of its sides, the other being similar to it. Fig. 3 is a representation of the parts of the machine which move round within the steam vessel, and Fig. 2 represents the interior of Fig. 1, with its lid removed. The pipe A, at Fig. 1, receives the steam from the boiler, to which is connected a valve box, of any usual construction, by which to regulate the admission of steam. At B the eduction pipe is connected, leading from the upper apartment to the condensing apparatus, and turning in such a direction as may be most convenient for the discharging pump to be wrought by means of an arbor, turned by the axle of the machine; on which arbor is a small fly wheel, for the purpose of regulating the inequality of the crank to which the

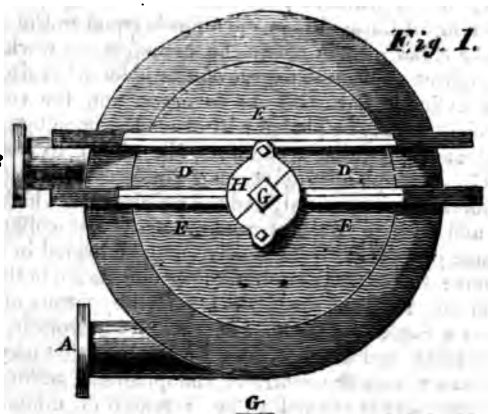
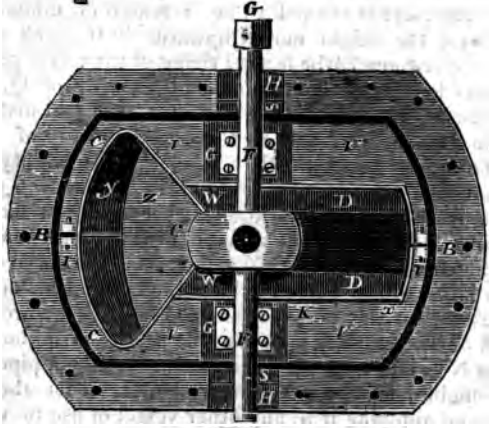


Fig. 1.



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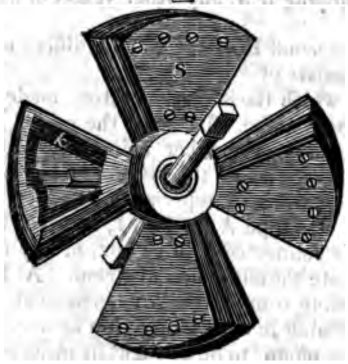

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pump rod is attached. D D is a middle part of the steam vessel, furnished with flanges for the purpose of screwing it to E E, and also for receiving the lid; by which means the partition within is secured to its place, in the middle of the machine, and the lid may easily be removed for the purpose of rectifying and repairing the internal structure. G is the square part of one end of the axis of the machine, over which is placed a gland H, divided into parts, in order that it may be put on over the square, and properly embrace the round part of the axis. Within this gland is a stuffing-box for the purpose of keeping the axle both air and steam tight. In one side of the lower apartment of the steam vessel is a small opening, secured by a lid, for the purpose of cleaning that part of the machine.

Fig. 2 represents the partition within the steam vessel, which may be made either of brass or iron, or of both those metals combined. B B is the lower flange, the upper part being taken away. C C are the two openings or passages for the vanes: these the inventor calls vane-ports, and to obtain a proper idea of their figure, it must be observed that the largest vane-port is formed by the exterior portions of two cones *z*, and at *y*, by a portion of the concave part of a sphere. The extent of this passage throughout must at least be equal to ninety degrees of a circle, and the vanes of a sufficient width, so that two of them may always make their entrance into the vane ports before the other two make their exit. The edge, *c c*, may, therefore, be supposed to descend into the lower apartment one half of their depth, and to rise the other half to meet the eye; but it is not necessary that *z* be so deep all the way as *y*, but converge towards the centre of the machine. This is the ascending vane port; the descending one is included between D D, which are rabbets or seatings for receiving a packing; and *x* represents a rising edge, so as to obtain a depth at least equal to the thickness of the vanes; one half of which edging is below, and the other half above the main axis. These edges receive two metal plates, fixed down with screws on them, for the purpose of confining the packing. The part E is also formed spherically, and is provided with a packing groove, which meets the edge of metal in the middle of the vanes, *k*, Fig. 3. F F is the main axle of the machine, laid in its place without the vanes; one end of which is to perform the work required, and the other is applied to the discharging pump. At D D the packing extends to W W, so as to embrace the nave as well as the descending vane, by which means both the nave and the vanes move steam tight in their revolutions. *v v v v* is that part of the partition which forms a plane at the axis of the globe, and is secured in its place by being seated in a rabbet with the usual jointing materials on the interior margin of the steam vessel. G G are two brasses let down into the partition, and they are raised or depressed by screws as adjustment may require. At *t t* spaces are left for packing round the axle; and the upper brasses which keep down the axle serve also to keep it in its place. At H H are the stuffing boxes mentioned in Fig. 1; they have a division plate of metal in them, so that *s s* being supplied with steam

from the valve box, the packing of each side of these vacuities are rendered air-tight. The manner in which the partition and vane ports are constructed, is by rivetting the two parts *v v v v*, together, by means of flanges at I I, first having mounted them on an axis, to correct, by turning, (either by hand or otherwise) the want of smoothness and truth from the casting; and when this is done the main axle is fixed to its place as a guide by which to set up the four vanes, as at Fig. 3, where, by a mere inspection, it is plain how this is performed. The open vane exhibits a frame of metal, which receives a plate on each side: these plates, with the edge of metal, K, cast with the frame, form grooves and vacuities to receive the packing. The nave being hollow receives two iron axles, which are curved in the middle, and there cross each other.

The manner in which they receive the vanes is shown by the figure; also how the packing renders them steam tight on the spherical part of the nave, and that when one of them is moved, its opposite vane on the same axle must also be moved. The main axle is turned true by rivetting the two parts together at the nave, and re-rivetting them after the cross axles are set in their places. All the several parts of the machine being then put in their respective situations, it is very evident that when steam is admitted into the lower apartment the rising vane, which occupies the largest passage, must overpower the other in its descent; and that, if by any means one of the vanes be turned a quarter of a revolution, it must at the same time carry with it the one which is connected on the opposite side of the nave; and this turning is effected by fixing with screws a block of wood, on the partition at K, in the form of a strong bracket. This block will not permit the ascending vane to pass it without being turned on its edge, by which means the one below is turned at the same time, to present its broad surface to the large vane port. It may be necessary to remark that when the machine is to be set at work, the steam is not admitted into the upper apartment of the vessel, to exclude the air, but enters immediately from the valve box to the eduction or discharging pipe, in order to preserve the grease which is made use of to lubricate the internal moveable mechanism of the engine.

We cannot express our opinion on this ingenious machine better than Dr. Gregory, who thus remarks :—

"Is there not some ground for fear that in this contrivance, besides the force lost by the action of the steam upon the edges of the vanes, there will be considerable loss arising from the greater friction attending its operations than those of a common steam engine? In this steam wheel there will be a great quantity of rough surface (that of the stuffing) exposed to frequent contact, and consequent resistance to the moving from the fixed parts; besides, as the stuffed parts are here of great extent with regard to the magnitude of the machinery, and exhibit rapid variations of shape, they may when brought into constant work, be found difficult to keep in order."*

* Gregory's Mechanics' Art. Steam Engine.

Mr. R. Wilcox, of Bristol, obtained a patent in 1804 for lessening the consumption of fuel, by using steam of greater elasticity than common: he proposed in some instances to raise his steamto the pressure of 150 pounds on the square inch.

Mr. Woolf's steam engine is also a most ingenious application of a property which steam possesses: the improvement is founded on a very important discovery which he made respecting the expansibility of steam when increased in temperature beyond the boiling point, or 212° of Fahrenheit's thermometer. It had been known for some time (and for this discovery the world is indebted to Mr. Watt,) that steam acting with the expansive force of four pounds the square inch against a safety valve exposed to the atmosphere, is capable of expanding itself to four times the volume it then occupies, and still to be equal to the pressure of the atmosphere. Mr. Woolf discovered that, in like manner, steam of the force of five pounds the square inch can expand itself to five times its volume; that masses or quantities of steam of the like expansive force of six, seven, eight, nine, or ten pounds the square inch can expand to six, seven, eight, nine, or ten times their volume, and still be respectively equal to the atmosphere, or capable of producing a sufficient action against the piston of a steam engine to cause the same to rise in the old engine with a counterpoise of Newcomen, or to be carried into the vacuous part of the cylinder in the engines of Messrs. Boulton and Watt; that this ratio is progressive, and nearly (if not entirely) uniform, so that steam of the expansive force of 20, 30, 40, or 50 pounds the square inch of a common safety valve will expand itself to 20, 30, 40, or 50 times its volume; and that, generally, as to all the intermediate or higher degrees of elastic force, the number of times which steam of a given temperature can expand itself is nearly the same as the number of pounds it is able to sustain on a square inch exposed to the common atmospheric pressure; provided always that the space, place, or vessel, in which it is allowed to expand itself, be of the same temperature as that of the steam before it be allowed room to expand.

Respecting the different degrees of temperature required to bring steam to, and maintain it at, different expansive forces above the weight of atmosphere, Mr. Woolf found, by actual experiment, setting out from the boiling point of water, viz. 212°, at which degree steam of water is only equal to the pressure of the atmosphere; that in order to give it an increased elastic force equal to five pounds the square inch, the temperature must be raised to above 227½°, when it will have acquired a power to expand itself to five times its volume, still equal to the atmosphere, and capable of being applied as such in the working of steam engines, according to the invention; and with regard to various other pressures, temperatures, and expansive forces of steam, the same are shown in the following table:—

	Pounds per square inch		Degrees of heat.		Expansibility.	
Steam, of a greater degree of elasticity than the atmosphere, acts with a force of	5	at a temperature of	227½	it possesses a power of expanding itself to	5	times its volume, and continue equal to the pressure of the atmosphere;
	6		230¼		6	
	7		232¾		7	
	8		235¼		8	
	9		237½		9	
	10		239⅓		10	
	15		250½		15	
	20		259½		20	
	25		267		25	
	30		273		30	
	35		278		35	
	40		282		40	

and so in like manner, by small additions of temperature, an expansive power may be given to steam to enable it to expand to 50, 60, 70, 80, 90, 100, 200, 300, or more times its volume, without any limitation but what is imposed by the frangible nature of every material of which boilers and other parts of steam engines have been or can be made: and prudence dictates that the expansive force should never be carried to the utmost the materials can bear, but rather to be kept considerably within that limit.

Having thus briefly explained the nature of Mr. Woolf's discovery, we shall proceed to give a description of his improvements grounded thereon. Mr. Woolf in his specification states,—" that in describing his invention, he has found it necessary to mention the entire steam engine and its parts, to which, as an invention well known, he neither can nor does assert any exclusive claim: he observes, however, that from the nature of the aforesaid discovery and its application, there can be no difficulty in distinguishing his said improvements from the improved engine of Mr. Watt as to its other common and well-known parts; and then gives the following account of an engine, embracing his new improvements.

" If the engine be constructed originally with the intention of adopting my said improvement, it ought to have two steam vessels of different dimensions, according to the temperature or the expansive force determined to be communicated to the steam made use of in working the engine; for the smaller steam vessel or cylinder must be a measure for the larger. For example: if steam of forty pounds the square inch is fixed on, then the smaller steam vessel should be at least one fortieth part the contents of the larger one; each steam vessel should be furnished with a piston, and the smaller cylinder should have a communication both at its top and bottom (top and and bottom employed here as relative terms, for the cylinders merely may be worked in a horizontal, or any other required position, as well as vertical); the small cylinder, I say, should have a communication, both at its top and bottom, with the boiler which supplies the steam, which communications, by means of cocks or valves of any construction adapted to the use, are to be alternately opened and

shut during the working of the engine. The top of the small cylinder should have a communication with the bottom of the larger cylinder, and the bottom of the smaller one with the top of the larger, with proper means to open and shut these alternately by cocks, valves, or any other well known contrivance. And both the top and bottom of the larger cylinder or steam vessel should, while the engine is at work, communicate alternately with a condensing vessel, into which a jet of water is admitted to hasten the condensation, or the condensing vessel may be cooled by any other means calculated to produce that effect. Things being thus arranged, when the engine is at work, steam of high temperature is admitted from the boiler to act by its elastic force on one side of the smaller piston, while the steam which had last moved it has a communication with the larger steam vessel or cylinder, where it follows the larger piston, now moving towards that end of its cylinder which is open to the condensing vessel. Let both pistons end their stroke at one time, and let us now suppose them both at the top of their respective cylinders, ready to descend; then the steam of forty pounds the square inch entering above the smaller piston, will carry it downwards, while the steam below it, instead of being allowed to escape into the atmosphere or applied to any other purpose, will pass into the larger cylinder above its piston, which will take its downward stroke at the same time that the piston of the smaller cylinder is doing the same thing; and while this goes on, the steam which last filled the larger cylinder, in the upward stroke of the engine, will be passing into the condenser during the downward stroke. When the pistons in the smaller and larger cylinder have thus been made to descend to the bottom of their respective cylinders, then the steam from the boiler is to be shut off from the top and admitted to the bottom of the smaller cylinder, and the communication between the bottom of the smaller and the top of the larger cylinder is also to be cut off, and the communication between the top of the smaller and bottom of the larger cylinder; the steam, which in the downward stroke of the engine filled the larger cylinder, being now opened to the condenser, and the communication between the bottom of the larger and the condenser shut off; and so on alternately, admitting the steam to the different sides of the smaller piston, while the steam last admitted into the smaller cylinder, passes alternately to the different sides of the larger piston in the larger cylinder, the top and bottom of which are made to communicate alternately with the condenser.

"In an engine working with the improvements which have been just described, while the steam is admitted to one side of the piston in the smaller cylinder, the steam on the other side has room made for its admission into the larger cylinder, on one side of its piston, by the condensation taking place on the other side of the large piston, which is open to the condenser; and that waste of steam which takes place in engines, worked only by the expansive force of steam, from steam passing the piston in the smaller cylinder, is received into the larger.

"In such an engine, where it may be more convenient for any particular purpose, the arrangement may be altered, and the top of

the smaller made to communicate with the top of the larger, and the bottom of the smaller with the bottom of the larger cylinder; in which case the only difference will be, that when the piston in the smaller cylinder descends, that in the larger will ascend, which, for some particular purposes may be more convenient than the arrangement before described." *

Mr. Woolf in his patent of 1805, proposed to use oil or fat to surround his cylinders in place of steam, previously used to prevent the waste of caloric. He also proposed to surround his piston with mercury, or employing upon it such a column of it as might be equal to the pressure of the steam. But Mr. Woolf possesses much greater claim to notice by his invention of a most excellent method of tightening the packing of pistons. It is well known that the piston of a steam engine by continued working becomes easy, and by allowing steam to escape past it occasions a considerable waste; so that it is necessary in the common plan to take off the top of the cylinder in order to get at the screws or supply the piston with fresh packing.

Mr. Woolf obviates this difficult and laborious operation by a method of tightening the screws without in the least disturbing the cover of the cylinder, which he thus effects.

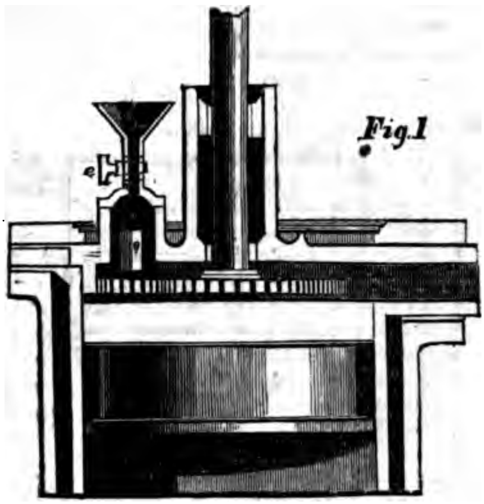
He fastens each of these screws into a small wheel (*c c c c c*, *Fig.* 2) which are all connected with each other by means of a central wheel *d d*, which works loose upon the piston rod in such a manner, that if one of the small wheels be turned, it turns the central wheel, and the latter turns the other four. The one that is to be first turned is furnished with a projecting square head, which rises up into a recess in the cover of the cylinder. This recess is surmounted by a cap or bonnet, which being easily taken off, and as easily put again in its place, there is little difficulty in screwing down the packing at any time. The parts are so clearly expressed in the drawing that no further description is necessary to make anyperson comprehend it.

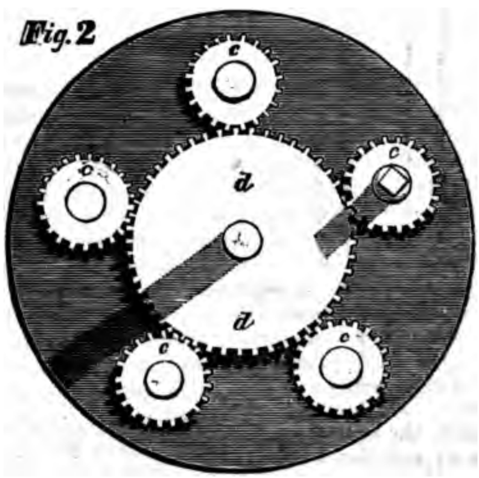
The other method is similar in principle, but a little different in construction. Instead of having several screws all worked down by one motion, there is in this but one screw, and that one is a part of the piston-rod: on this is placed a wheel of a convenient diameter, the centre of which is furnished with a female screw. This wheel is turned round, *i. e.* screwed down by means of the pinion *o*, *Fig.* 1, which is furnished with a square projecting head rising into a recess of the kind already described. The ring is prevented from turning with the wheel by means of two steady pins.

Mr. James Boaz, of Glasgow, obtained a patent in 1805, for a machine for raising water on a plan somewhat similar to Savery's:

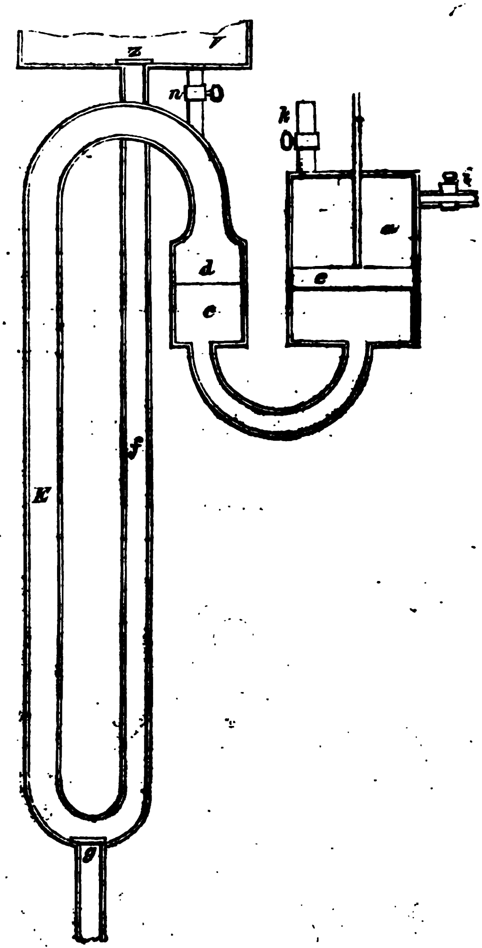
a is the steam cylinder; *i* the pipe from the boiler, having a stop cock; *k* a waste steam cock; *e* a floating piston attached to a piston rod. *E* a pipe which generally contains hot water; *f* water pipe, having a valve at *g* immersed in the well, and delivering the water into the reservoir *v*, through a valve *z*. The air which accumulates in the receiver escapes at *n*; *v* the raised water cistern; *d* rarifying or exhausting vessel.

* Philosophical Magazine.





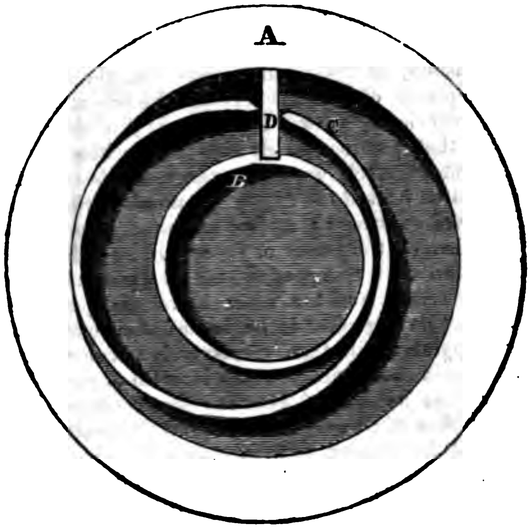
The whole being filled with mercury and water, shut the air valve *s*, and open *i*, the steam from the boiler will rush into the receiver, and after heating the water, it presses on its surface, forcing the mercury up into the exhausting vessel *d*. The water above *c*, and in the pipes *E f*, will be forced up into the cistern *v*, in a quantity nearly equal to the space occupied by the steam in the receiver. When the piston has been depressed as far as is necessary



or its stroke, the self-acting mechanism attached to its rod, shuts *i*, and opens *k*; and the mercury being now at liberty to act by its gravity, descends from the exhausting pipe, and raises the piston to its first position; and the steam which pressed it downwards being now allowed to flow into the atmosphere, the fall of the mercury from *d* into *a*, leaves a vacuum in *d*, into which the water in the well is pressed by the atmosphere, and again fills it. The valve at *g*, prevents its return to the well in the operation of forcing; and the valve *x* prevents its fall from the cistern when the vacuum is made in *d*.*

* Repertory of the Arts.

In the year 1805 Mr. John Trotter, of London, obtained a patent for a Rotative Engine, which may be thus illustrated.



A, a circular piece called the outer barrel. B the inner barrel. C, a circular piece called the eccentric. D, a piece called the sweep, which shuts completely across the space between the inner and outer barrels, so as to intercept the communication in that part. There are caps or covers at each end of the pieces, which close the space between the two barrels, and serve, by grooves or other well-known fittings, to keep the other parts in their respective places.

The situations and motions of the parts herein enumerated are as follow:—1st, the barrels are concentric; 2ndly, the sweep is capable of moving or revolving (either by absolute or rotative motion) through the space between the barrels: it may be either separate from the barrels, or it may be fixed to either or both of them, and in the last mentioned cases, the barrel or barrels to which the sweep shall or may be so fixed, will necessarily move along with it. The sweep is so well fitted or fixed that no fluid shall pass through the places of its opposition or junction with the barrels or caps, or as that the quantity suffered to pass shall be inconsiderable. 3rdly, the eccentric is of such a diameter and so wrought, that its concave and convex surfaces shall touch the inner and outer barrels, and that the places of contact shall not admit any fluid to pass between the eccentric and each barrel severally, or at least, that the quantity which may so pass shall be inconsiderable. The eccentric is capable of rotation in its own plane or periphery, but not otherwise with relation to the caps; and it has a long perforation through which the sweep is put, consequently the sweep and the eccentric will always move together.

It may be pointed out, as distinguishing characters of this engine, that, whenever the sweep is moved, the space which is comprehended between the barrels and the eccentric, and the posterior or hinder surface of the sweep will be continually enlarged, and that the space which is in like manner comprehended between the barrels and the eccentric, and the anterior or fore surface of the sweep, will be continually diminished, excepting that, soon after the sweep has passed at or near the places of contact between the eccentric and the outer barrels, the posterior space will be suddenly diminished by the separation of all that portion which was comprehended between the eccentric or outer barrel, in consequence of the place of contact having come to be behind the sweep. And also, that soon after the sweep has passed at or near the place of contact between the eccentric and the inner barrel, the posterior space will be suddenly diminished by the separation of all that portion thereof which was comprehended between the eccentric and the inner barrel, in consequence of the place of contact having come to be behind the sweep; and the said portions so separated will then respectively become portions of the anterior spaces, in consequence of the interval or distance which will at the same time be formed between the eccentric and the barrel immediately before the sweep. Whence it is manifest, that if any fluid be forced by gravity, elasticity, or otherwise, through one or more apertures from without into the space on one side of the sweep, that pressure will carry the sweep forward and the eccentric along with it, together with such barrel or barrels, as by the construction shall or may be fixed to the sweep; and, moreover, if there be any one or more other apertures communicating from the opposite side of the sweep, in order to allow the said fluid to escape, or be carried off or condensed, or otherwise disposed of, all such portions of the said fluid as, by the change of situation of the sweep hereinbefore described, shall be separated from occupying part of the space behind the sweep, and shall come to occupy part of the space before the same, will, in fact, so escape or be carried off, or condensed, or disposed of, and the rotatory motion of the engine will be kept up, and may be applied as a first mover to other works, so long as a due supply of the said fluid shall be afforded.

It is manifest, that in case the rotatory motion of the said engine be produced by any force not applied to its internal parts in the manner hereinbefore described, and any fluid be admitted to communicate with the posterior space within the same, the said fluid so admitted will flow into or be absorbed in the said space, which becomes continually enlarged, and will afterwards be transferred to, and drawn out of, the anterior space which becomes continually diminished as aforesaid: and that, in this application, the said engine may be used to raise or give motion to fluids in any direction whatever.*

This rotative engine possesses originality and ingenuity which cannot be said of many we have enumerated. Our readers will perceive that the reasons which we have given for the failure of

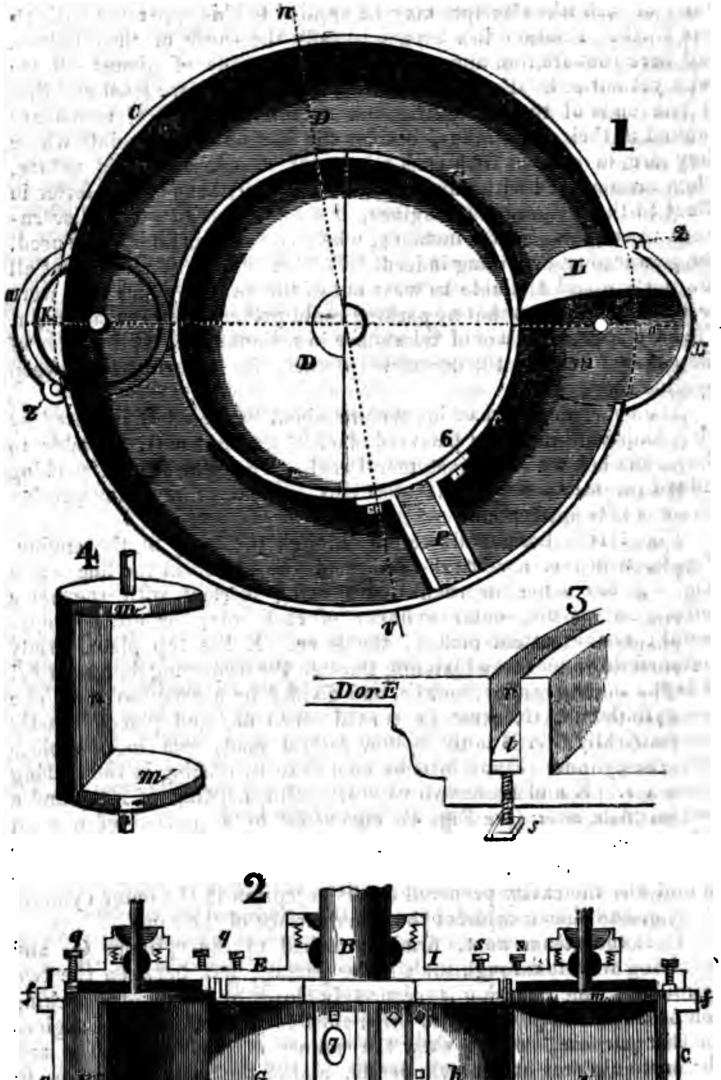
* Specification of Patent.

many of such like attempts may be applied to this apparatus with no less truth. Friction has been generally the cause of their failure, and here that friction appears more than double of almost all we have yet noticed. For to the friction of the sweep we must add that of the ends of the concentric and eccentric cylinders, which are packed at their peripheries, besides the friction of the points where they are in contact with each other. If machines of this nature, when encumbered with only one inner cylinder, have been inferior in effect to the reciprocating engines, it cannot require much discernment to see that, in this instance, where two such cylinders are used, the power must be trifling indeed. Further, it may be added, that all the parts would be liable to wear out of the form in which they were first constructed, so that no packing could preserve them steam-tight. This we apprehend would take place in a short time, at the sides of the cavity formed in the eccentric cylinder, for allowing the sweep to slide through it.

We consider the machine we are about to describe, invented by Mr. Andrew Flint (and patented about the same time), as liable to the objections we have just mentioned. The difficulty of packing indeed (all others out of the question), appear to be an insuperable barrier to its application.

Fig. 1 is a horizontal section through the body of the engine. Fig. 2, which is a vertical section of the same, in the line *n v* of Fig. 1; the same in each figure being marked with the same letter. C is the outer cylinder of cast iron, or other proper metal; D the bottom plate of the same. E the top plate, firmly fastened down by screws passing through the projecting flanges at *f f*. G is the inner cylinder, hollow, and divided by a partition at *h*. The two cylinders, C G, must be turned very true, and placed exactly concentrically. A B is the hollow central shaft, cast in one piece with the cylinder G, and forming an axis to it, turning in the stuffing boxes I I. K and L are two valves, each consisting of a top and a bottom plate *m m* (see Fig. 4), connected by a portion of a solid cylinder *n*. The plates *m* are sunk into the plates D and E, so as to lie flush with their inner surfaces; and the connecting piece *n* lies in and fills the cavity prepared for its reception in the outer cylinder C, at *o*, and thus completes the inner surface of the same.

P is the steam float, firmly attached to the cylinder G, and revolving with it through the circular passage left between the two cylinders; which passing it accurately closes by means of a packing composed of hemp, tallow, or other substances used in steam engines for that purpose. *q q q q* shew the manner of packing the top and the bottom plates of the cylinder G, and of the valves K and L, to prevent the escape of the steam between them and the top and bottom plates of the outer cylinder. This is alike in all these instances, but will be most readily understood by comparing Fig. 1. with Fig. 3, which shews the parts to a large scale. *r* is a circular groove sunk in the inner surface of the plates D and E, and concentrical to the axis of the cylinder G, and of the valves K and L respectively. In this groove is placed a metal packing ring *t*, and it is then to be filled up with a packing, against which the surfaces of the said plates of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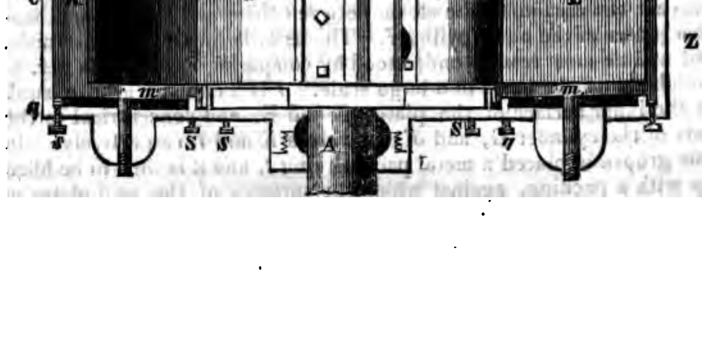
Dor E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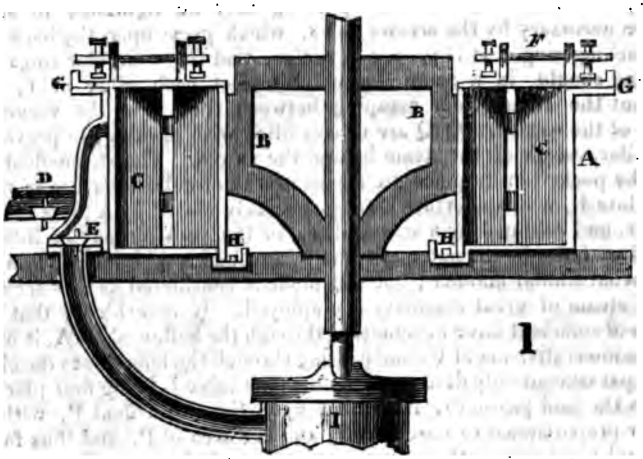
G, K, and L work; and this packing may be tightened in any degree necessary by the screws *s s s s*, which press upon the back of the packing-ring. It is proper to notice, that these circular rings of packing should, in a small degree, intersect each other at 1, to prevent the steam from escaping between them into the vacuous parts of the engine. Q Q are chases filled with packing, to prevent a similar escape of the steam behind the valves. The steam-float P is to be packed in its place by means of the circular aperture in the top plate E, which aperture must be securely closed by a plate fitted into it, and confined by a strong dog; or the packing may be introduced by holes in the outer cylinder C, which may be closed in a somewhat similar manner; but this mode is considered as less secure when steam of great elasticity is employed. It is evident, that if steam of sufficient force be admitted through the hollow shaft A, it will fill the lower division of G, and passing through the hole 6 into the circular passage already described, where (the valve L being first placed across the said passage), it will act upon the steam-float P, with a power proportioned to its elasticity and the area of P, and thus face it round till it passes the valve K, the steam before it finding a vent by the hole 7, into the upper division of G, and so through the shaft B into the condenser. If now the valve K be shut, the re-action, as it is termed, will take place against it, and the valve L may be opened to allow free passage to the steam-float. These valves are placed in the required position by the working gear.*

It is our business next to describe the inventions of Mr. R. Wilcox, of Bristol, whom we have already noticed in another part of this chapter. He obtained a second patent in 1805, for a number of rotative engines, which are, in our opinion, exceedingly ingenious. The work, entitled Stuart's History of the Steam Engine, has passed over the contrivances of this gentleman, by remarking that they vary from Mr. Flint's only in some trifling alterations of the cocks and steam pipes. But it will be seen that this is extremely incorrect, as some of the plans described differ entirely not only from Mr. Flint's, but from every previous attempt of the kind.

Fig. 1 is a vertical section of one of his plans as attached to the common condenser for the purpose of shewing one of the most simple and compact arrangements, where the steam is condensed. A the outside case or cylinder fixed to the framing of the condensing cistern, or any other more suitable and convenient framing that the engineer may find most appropriate or suitable to the locality of the premises, where the engine is to be erected. B B the inside or revolving cylinder, attached to and connected with the vertical shaft, which is the first mover, and which gives a rotative power to any description of machinery requiring the same, through the medium of a spur wheel fixed to the said shaft, when a vertical motion is required; or with a bevil gear wheel, where an horizontal motion is wanted. C C moveable pallets, gates, or valves, for regulating the operation of the steam in the engine; one of

* Specification of Patent.



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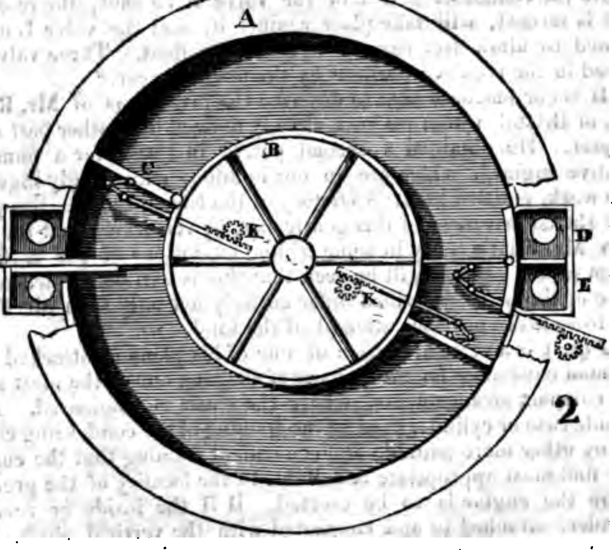

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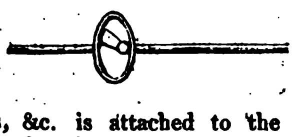

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the said pallets, &c. is attached to the fixed cylinder A, and the other to the interior cylinder B, as is more distinctly seen in *Fig*. 2, and the references annexed. D the steam valve for

the admission of steam between the said pallets, E the exhausting valve for the egress of steam. The gear required for opening and shutting the valves D and E, and for opening and shutting the said pallets or gates C C, is so nearly similar to that of common engines, that it would be useless to describe it more than the said valves D and E require to be opened and closed at the same time, whereas, in general, they are opened and shut alternately by the plug tree, or other simple and well known means. F the top of the cylinder, composed of a ring of metal, for pressing the packing round the moveable cylinder, the lid is screwed down with screws, as is usual in securing the lids or tops of cylinders. G G two rings of metal pressed by screws, from a lever secured to the top of the cylinder F, for compressing the packing, and securing the joint of the cylinders A B. H H a circular channel into which the revolving cylinder B works, for the purpose of preventing the ingress of air or other fluids into or by the said interstice or channel, and which is packed with hemp and grease, and pressed in such manner with a ring as thereby to render the engine more efficient, by keeping it perfectly tight. I the common condenser, the air pump of which, is wrought by studs or stops projecting from the horizontal shaft, or any other simple or effectual way the engineer may think proper, as is more distinctly seen in *Fig.* 3, which is the end view of the shaft, and the side view of the piston rods; the operation of which is so obvious, as not to require elucidation. *Fig.* 2 exhibits the bird's eye view of *Fig.* 1, with the top of the cylinder and compressing rings removed, to show the operation or apparatus for opening and closing the pallets, gates, &c. and and also part of the flanges removed to show the situation of the valves. The letters of reference in this case of *Fig.* 2, are placed upon the same parts of the engine as in *Fig.* 1, which it would be superfluous to recapitulate. C C the pallets, &c. formed of two or more pieces of metal; one part of the said pallet is permanently secured to each cylinder A and B, whilst the other part or parts turn on a joint or hinge; which said joint or hinge is made steam tight or secured, together with the whole of the edges coming in contact with the cylinder, with a hemp cloth stuffed, wadded, or folded together, or by other similar materials, capable of stopping the passage of steam, and which must be screwed or otherwise fastened on the front of the said pallet; and by the pressure of the steam it is pressed or brought in contact with the said pallet or cylinders, and thus it effectually prevents the escape of steam, or other fluids by or with which the engine is wrought. K K two racks and pinions communicating by a straight and parallel bar, working through a stuffing box in the sides of each cylinder, whereby the said valves are opened and shut, whilst passing each other, from the external part of the engine by a piece projecting from the upper or lower part of the fixed cylinder, which may be placed at the option of the engineer; which said piece in its passage comes into contact with the gear connected with the said pallets, and thereby with any of the well known simple methods or gear used for opening and shutting of valves in the present steam engines. The

gates, &c. of the engine are opened and shut as occasion requires. L, *Fig.* 2 exhibits a second gate, &c. which in this case slides backwards against a straight parallel surface during the time the pallet in the revolving cylinder is passing when the said gate is sliding by the gear against the revolving cylinder, as in the drawing. The said gates may be opened and closed in a variety of ways, such as a spindle ground into the bottom of the fixed cylinder, and connected by a link to the gate internally, or a crank or compound lever may be applied instead of the rack and pinion externally.

In another plan Mr. Wilcox proposes a piston firmly fixed to the interior cylinder, and instead of gates or pallets, he has a plate of metal which is drawn into a recess as the piston passes, and returned immediately into the cylinder, so as to become an abutment for the action of the steam.

In this plan A is the outside stationary cylinder. B the inner cylinder. C the top of the cylinder and rings, as in *Fig.* 1 and 2,

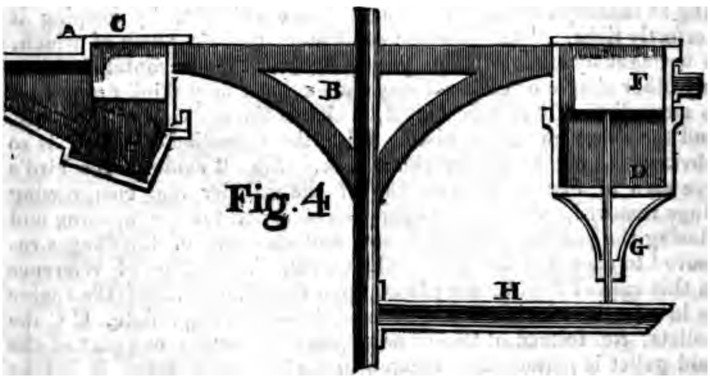


Fig. 4

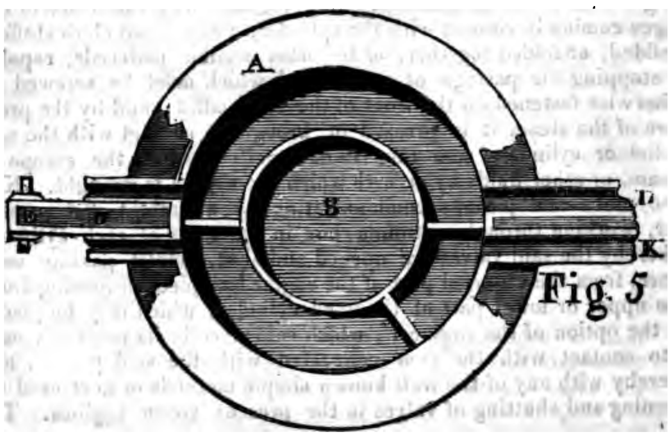


Fig. 5

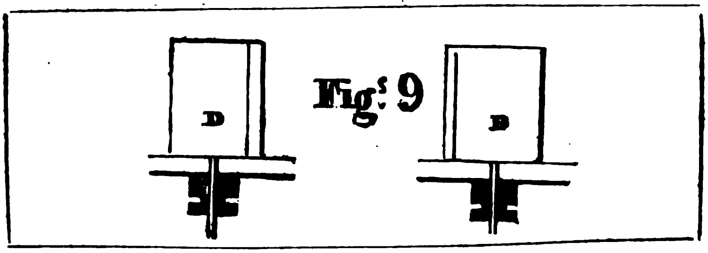


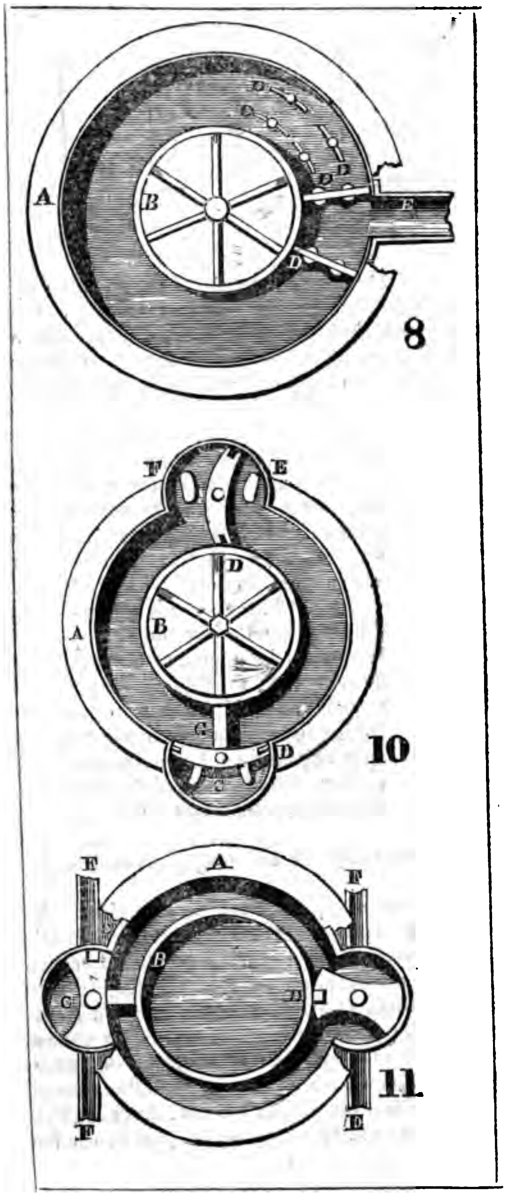
Fig. 9

already explained. D a plate of metal, as represented by the dotted lines, made very straight, smooth, and parallel, as it respects its thickness. E a small shaft or axle, working through a box, or a receptacle fixed on the outside of the cylinder A, allowing room sufficient for the said plate to drop clear off to the bottom of the cylinder, whilst an accurate incision is made in the bottom and side of the cylinder sufficient to admit the said plate D to slide freely up and down, which is effected by a rack and pinion, or lever, or any other simple contrivance attached or connected to the extremity of the shaft E; by which means the steam is caused to act on the same or a similar principle, as in Fig. 1. F, Fig. 4, presents a second way of producing the same effect, namely, that of raising a plate of metal through an incision made in the bottom of the cylinder A, from a box fixed underneath the cylinder, through the medium of a parallel bar working through a stuffing box; whereby the said plate D is raised or depressed, as the working of the engine requires.

"Fig. 5 is the bird's-eye view of Fig. 4, with the same general letters of reference to their respective parts, as in Fig. 4. K the steam passage. L a passage leading or communicating with the condenser, when the steam is required to be condensed. Here it may be necessary to remark, that, although the plate D is shown as rising upwards, as being the most convenient way; nevertheless, the boxes necessary to receive the plates may be placed above the cylinder, and the plates may be raised in an oblique instead of perpendicular direction.

"Fig. 8 is the plan of another rotatory engine. A the outside fixed cylinder. B the inner or revolving cylinder. D D two or more pallets, working through a deep stuffing box, and turned by a lever or other power from the external part of the engine alternately flat or edgewise; the pallets D are fixed to the revolving cylinder; E is the steam passage, that to the condenser not being shown.

"Fig. 10 is the bird's-eye view of a rotary engine, as wrought with a cock or portion of a circle, whereby a similar effect is produced as in Fig. 1, by or with a portion of circles: in these figures, 8, 11, the lids of the cylinders are removed, and a part of the flanges where the circles or irregular cocks are used is broken off, to render the working parts conspicuous. A, the outer or fixed cylinder. B, inner or revolving cylinder. C C, the pallet, cock, or portion of a circle, fitted accurately into the circle it prescribes; with a spindle working through the top of the cylinder. D, the groove, into or against which



the part coming into contact with the revolving cylinder is secured with a piece of hardened metal, in order that the constant friction of the revolving cylinder shall not injure the pallet or cock. E the

passage to the boiler. F the passage to the condenser. G the pallet secured to the working cylinder. In this figure two portions of circles and cocks are introduced, for the purpose of showing clearly their situations in different places, the same as in Fig. 10.

"Fig. 11 exhibits the bird's-eye view of a rotatory engine, as wrought by a cock or cocks, which regulate the steam instead of valves, and also act as the principal cock or pallet in the said engine. A the outer fixed cylinder. B the inner revolving cylinder, with a fixed pallet. C C the cocks, which are wrought from the external part of the engine, by a spindle passing through the top. D a piece of hard metal, introduced into the said cock, to resist the friction of the revolving cylinder, as explained in Fig. 10. E, steam passage. F, passage to the condenser."*

The first of Mr. Wilcox's plans (1 and 2) is, as far as we know, perfectly original. Its great complexity has been, no doubt, a great cause of its abandonment; if, indeed, it was ever tried. The number of racks, pinions, gates, pallets, joints, grooves, slides, and stuffing boxes, must instantly impress the mind of every one with an idea of its great inferiority to the most complex reciprocating engine.

The second scheme, (4 and 5) it will be perceived, resembles in its general principle one of Messrs. Bramah and Dickenson's engines, a description and plan of which will be found at page 70 of this work. The objections, therefore, which have been made against that plan, will apply equally to Mr. Wilcox's.

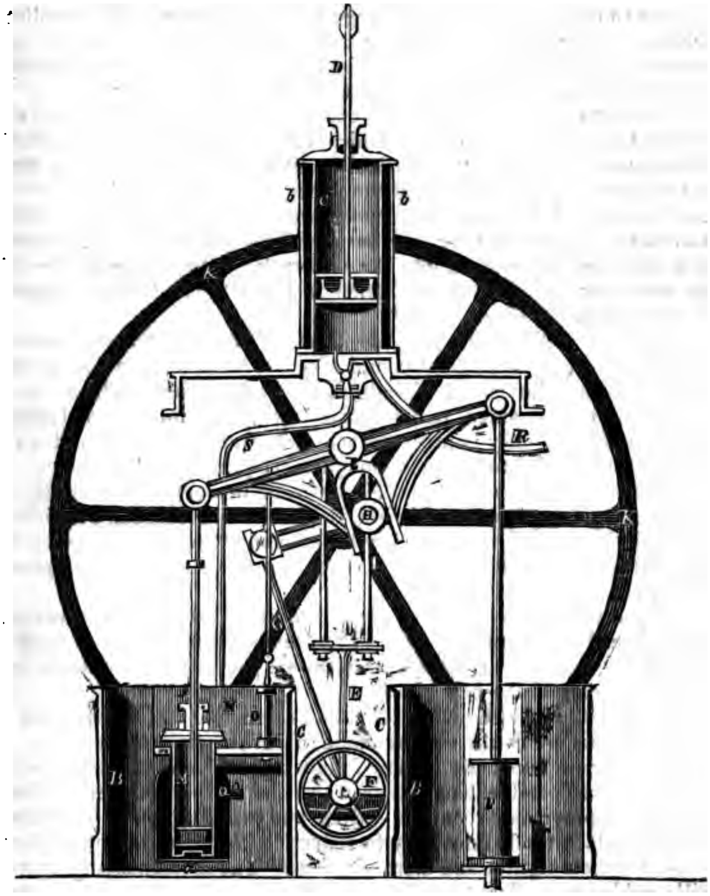
In the third plan (Fig. 8) we apprehend that a great waste of steam would arise from the difficulty of making the pallets, D, unite sufficiently close at the joints; besides that the complexity would be nearly as great as the first plan.

The fourth and fifth plans (10 and 11) resemble that of Mr. Flint's so nearly that we doubt not they failed from the same cause.

In the year 1807, Mr. Henry Maudslay, of London, obtained a patent for a Portable Engine, in which he introduced several ingenious improvements on the valves and working parts of steam engines, which tended not only to reduce the friction, but altogether to render them tighter and more compact. The accompanying figure will enable our readers to understand what these improvements were.

A represents a frame of thin cast iron, for the purpose of fixing the cylinder. B B are two cold water cisterns, of merely sufficient size to admit of easy access to the pumps within them; they communicate with each other by a pipe *a*. C is the cylinder surrounded by a casing (*b*) of copper or other material. The space between the cylinder and casing is filled with wool or some other imperfect conductor of heat; D is the piston rod joined to smaller rods carried down on each side of the cylinder to E, and having an opening or division so as to avoid interfering with the main shaft. These rods are at their lower ends fixed to a wheel F, with a fluted rim: from the centre of which a connecting rod, G, is carried to the end of the crank. The wheel F runs between two guides, *c c*, so as to preserve

* Specification of Patent.



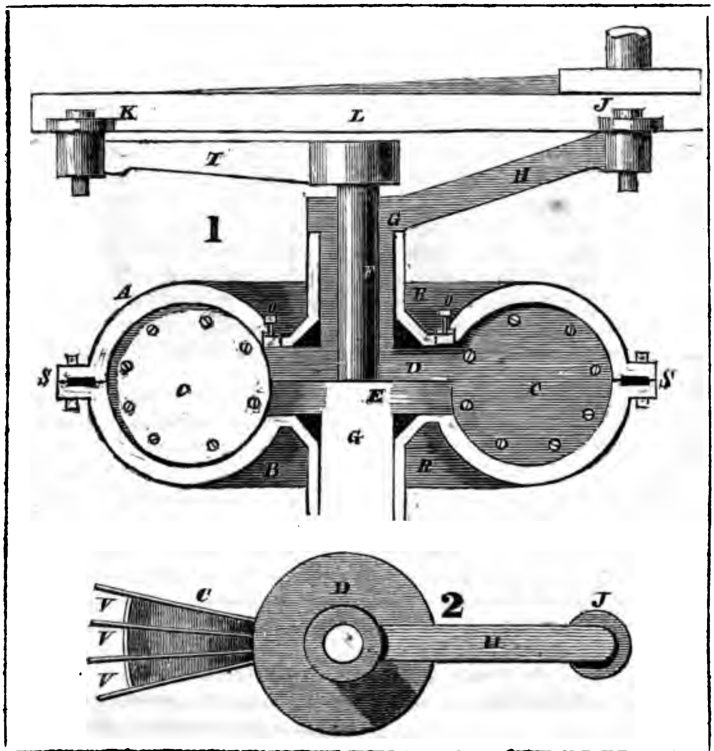
the rectilineal motion of the rods E, and the piston rod D. H is the crank, a three-throwed one. J a cross beam for working the pumps P O M; its motion is procured by having a fork underneath it, which embraces one of the cranks H, on which is a roller for reducing friction. By this means the fork, and consequently the beam and pump rods, is reciprocated by the revolution of the shaft. K K is the fly wheel; L is the condenser, containing the air pump M; N is the hot water cistern, and O the hot water pump; P the cold water pump; Q the injection cock; R the steam pipe from the boiler to the cylinder; S the eduction pipe. The steam is admitted into the cylinder by a four-way cock, which differs from that generally used by its being considerably more taper, which effectually prevents it from *jamming* by unequal expansion or contraction, an evil to which the common cock is liable.

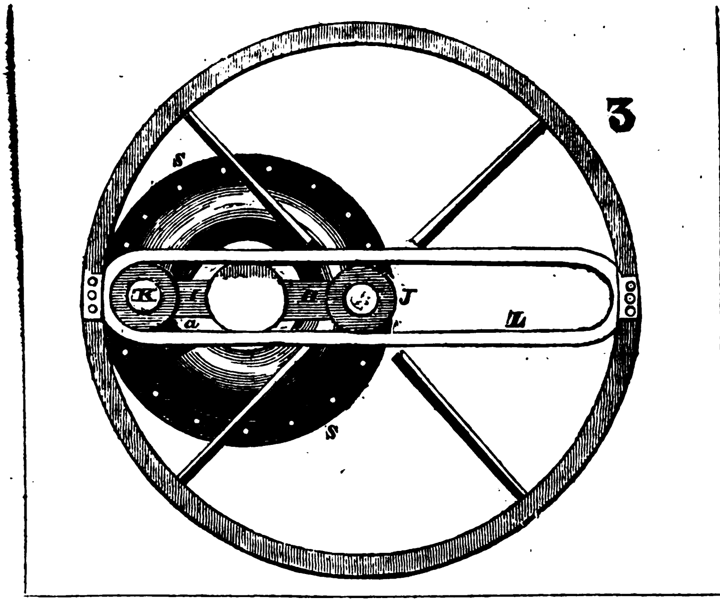
There are few machines which display more ingenuity, either by skilful arrangement or neatness, than this; and, as it regards its utility, it need only be said that long continued trials have fully established the great excellence of Mr. Maudslay's engine. We do not pass over this machine, therefore, with so short a description on account of any doubt respecting its merits; for were the length of our remarks to be governed by our opinion of the utility of any machine, they would in this instance extend over several pages. But however beautiful may be the arrangement of Mr. Maudslay's engines, this is not their sole merit; for Mr. M. has, by superior workmanship, and most careful attention to the selection of good materials, obtained the reputation of being one of the best manufacturers of steam engines in the world.

CHAPTER VI.

CONTENTS.—MEAD'S ROTATIVE ENGINE.—CLEGG'S STEAM WHEEL.—CHAPMAN'S STEAM WHEEL.—WITTY'S ROTATIVE FROM RECTILINEAL MOTION.—ONION'S STEAM WHEEL.—BLENKINSOP'S LOCO-MOTIVE ENGINE.—BRUNTON'S LOCO-MOTIVE ENGINE, OR MECHANICAL TRAVELLER.—DODD AND STEPHENSON'S LOCO-MOTIVE ENGINE.—TREVITHICK'S ROTATIVE ENGINE AND IMPROVED STEAM BOAT.—TURNER'S ROTATIVE ENGINE.—LOSH AND STEPHENSON'S IMPROVED LOCO-MOTIVE ENGINE.—ROUTLEDGE'S ROTATIVE ENGINE.—MALAM'S IMPROVEMENTS.—SIR W. CONGREVE'S STEAM WHEEL.—WRIGHT'S ENGINE.—PONTIFEX'S IMPROVEMENTS. — RIDER'S ROTATORY ENGINE.—MASTERMAN'S STEAM WHEEL.

We stated in our remarks on Hornblower's Steam Wheel, (described at page 77) that it had been claimed as an original invention many years after Mr. Hornblower obtained a patent for it, we alluded to the patent of Mr. T. Mead, of Hull, dated 1808, the specification of which describes a machine resembling in principle, though of a somewhat different form, to this engine of Hornblower's.





"A and B, Fig. 1, are two circular plates or shells of metal, similar in their construction, having their insides turned, or otherwise made very true and correct; A has its inside uppermost, and B its outside uppermost. Each of these circular plates or shells have a flange and semicircular cavity formed for the reception of the pistons which are afterwards described, and a recess or hollow part formed round its centre for a small circular plate to turn in. Near to the edge of each recess is a small groove running quite round it; in the bottom of each groove is placed a metallic ring, O O, capable of being adjusted by screws on the outside of each shell. At its centre is a hollow pipe or boss for the reception of the spindles, F and G. The plate A has also two holes, *a a*, Fig. 3, to which pipes are fitted, one to convey steam into the shells, the other to conduct it from them into a condenser, or wherever it may be required. C C two pistons with grooves round them to admit of a packing or wadding. D and E two circular plates to which the pistons are connected or made fast. F and G two shafts or spindles; the spindle G is made hollow to receive the spindle F, which passes through it. H and I two arms made fast to the two spindles; each arm, near its extremity, carries a wheel K and J, which are generally termed friction wheels. L a fly or a regulating wheel, fixed to one end of a shaft or moveable axis, having in its side opposite to its axis a groove running across its diameter for the reception of the friction wheels J and K, which wheels, when the pistons are put in motion, work in it, and give motion to the fly wheel and other machinery which

may be connected with it. R R the hollow plates or bosses for the spindles to work in; S S flanges by which the shells are fastened together. Fig. 2 is a front view of one of the pistons, with its circular plate, arm and friction wheel; J the friction wheel; H the arm; D a circular plate, and C the piston. V V V grooves for the reception of the packing or wadding, which is to be made fast therein. When the engine is to be put together, the arms are taken off from the spindles; the spindle F is then to be inserted in the hollow spindle G, which, with their respective pistons, are placed in one of the shells, and the one shell placed over the other; the shells are then fastened together with screws or otherwise, so as just to admit the pistons with their respective plates and spindles to turn round in their channels nearly steam-tight; the arms may then be made fast on the spindles, and the engine erected. Place the direction of its axis in an horizontal or lateral direction, parallel with the direction of the axis of the fly, but nearly as much out of that line as the length of one of the arms, H and I, taken from the centre of the spindle to the centre of its friction wheel, and at such a distance from the fly as to admit of the friction wheels moving freely in the groove on its face. By so doing the axis of the engine will be placed eccentric with the axis of the fly. The engine may be fixed in an iron or wood frame, and the fly supported in the same or a separate frame, in the position before pointed out. If the fly is then turned half way round upon its axis, one of the friction wheels will remain locked or held fast in the groove near its centre, and the piston with which it is connected remain nearly stationary in the steam chamber, between the holes *a a*, while the other friction wheel, with its arm, spindle, small circular plate and piston, make nearly one complete revolution, round their common centre of motion, or the centre of the engine. If the motion of the fly continue till it has made one complete revolution round its own axis, the friction wheel which was locked or held fast in the groove near its centre, will move off in the groove towards the circumference of the fly, and with its arm, spindle, small circular plate, and piston, make nearly one complete revolution round their common centre of motion, or the centre of the engine, and the other friction wheel in its turn remain locked, or held fast in the groove near the centre of the fly, and the piston with which it is connected remain nearly stationary within the steam chamber between holes *a a*; and so on, alternately, as long as the fly continues in motion. Instead of the hollow spindle G, and the solid spindle F, two other solid spindles may be used, by applying one to each small circular plate, and passing them through the opposite pipes or bosses, each having its arm and friction wheel as before, but working in separate grooves mounted on separate axles, and united by wheel work. When the engine is to be set to work by the force of steam, the steam is permitted to enter by one of the pipes into the steam chamber, where, by its elasticity, it will press or act upon both pistons nearly alike; and as one of the pistons is stopped or held fast by the aforesaid methods, the steam cannot pass into the other pipe that way, but will force the other piston round with its small

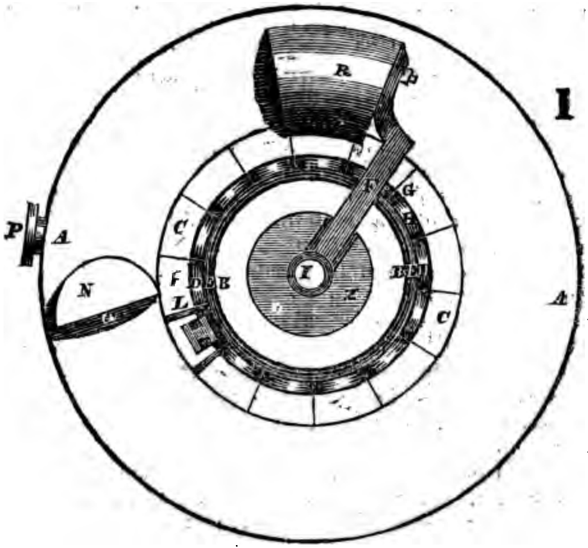
circular plate, spindle, arm, and friction wheel, and put the fly in motion, and continue it as before explained. A similar effect may be produced with a concave globe or sphere, having within it two moveable semi-circular leaves, (as a substitute for the pistons) with packings at their edges, and united in the centre or axis of the globe with joints or hinges, and having each of them an axis passing through the globe to receive the arms and friction wheels as before described, and with holes and pipes for the admission of steam."*

By referring to the aforesaid drawing of Hornblower's Engine it will be seen that principle of alternate revolution of two pistons is adopted, both in that and in this before us. But although there might not be that difference in Mr. Mead's engine to merit the name of an original idea, yet it is extremely ingenious; and the method whereby he has endeavoured to avoid the striking of the two diaphragms, is probably the nearest approach to a removal of that evil which we stated was the probable reason of the abandonment of Hornblower's plan. For here, by the aid of the fly wheel, the moving piston is gradually brought (like the piston of the reciprocating engine) to a state of rest, so that the striking would be almost done away with. This being the case, we feel much difficulty to satisfy ourselves as to the cause of failure: and, but for the assurance that it did actually fail, we should have almost expected that it would have exceeded in effect any rotative engine we have yet described. For although there is reason to believe that the wadding or packing would be torn out of its place in passing over the cavities for the admission and exit of the steam, yet that difficulty could be removed by the substitution of metallic packing. If this engine ever had a fair trial under circumstances where there were no local inconveniences, we confess we cannot see why its effect was not *equal at least* to that of a beam engine. It is true, the revolution is neither continuous nor equable, but this is no more the case with any engine in use, but on the contrary, a much greater mass of matter in others that is to be brought to rest at each change of motion.

Mr. Samuel Clegg, of Manchester, obtained a patent for a Rotative Engine in the year 1809, the principle of which is thus explained.

"Fig. 1 is the underside of a circular piece of cast iron, and of a diameter and thickness proportioned to the size of the engine. I is the common centre of the different circles shown on this piece. With any convenient radius less than that of A A describe the circle C C, and within the latter the circles D D and E E,—the radius of the latter being the least of those now named. From the uses of these parts, which will be immediately described, an idea of their relative dimensions will readily be inferred. Let that part of the surface A B, A B which is contained between the circles A and C, be plain. Between the circles C and D sink a circular groove C D of any given depth; and between the circles D and E let another circular groove be cut of the breadth D E, and of any given depth less than that of the groove C D. Let the remaining part of the surface A B, namely,

* Specification of Patent.



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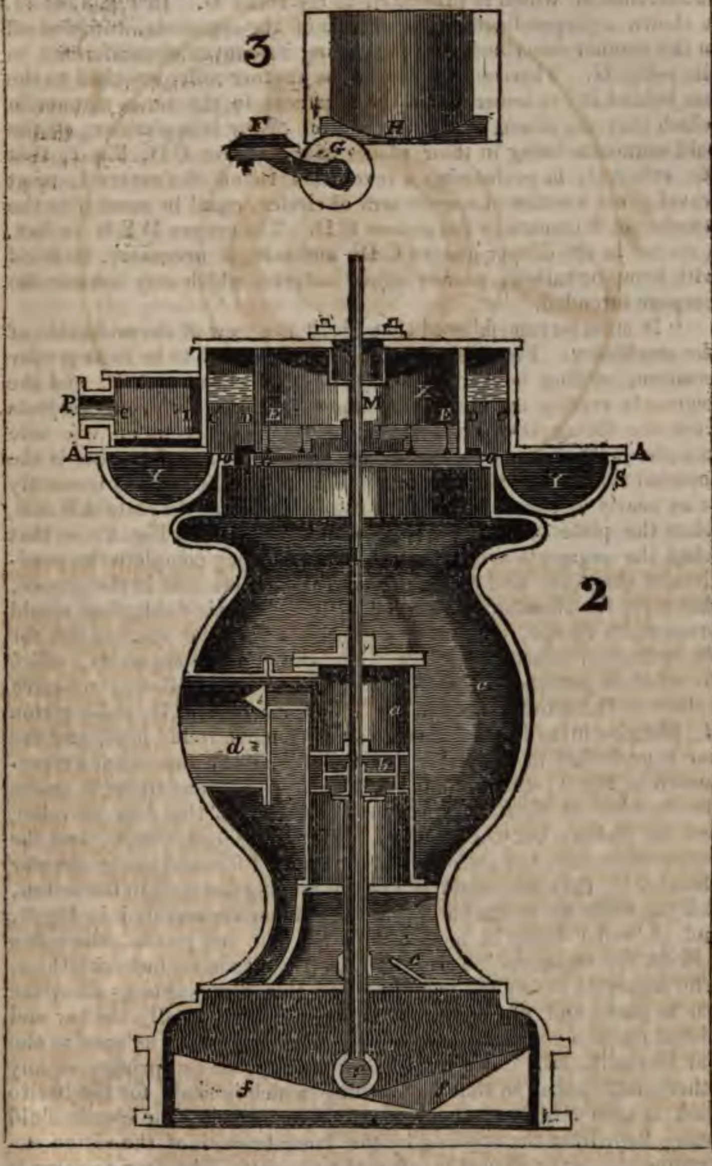
that included between E and B, be cut down to any depth less than the depth of the groove D E.

"Into the groove C D let such a number of segments of a circle be fitted as shall form a complete circle, excepting the space at L, which is occupied by adjusting screws or springs, to keep the segments close together. The segments are the breadth (or nearly) of the groove C D, and of a depth less than the depth of the groove C D. Those sides of them which apply to each other are to be ground together plain, and air-tight if possible. Their under surfaces, which are shown in Fig. 1, are to be flat, so that the whole may form one complete plain surface, excepting the space before mentioned, which is taken up by adjusting screws or springs L, which screws or springs are placed so far below the surface as to let a roller pass by them, which will be mentioned hereafter.

"Fig. 2 represents a vertical section of the plate and grooves of Fig. 1, resting upon a circular chamber or hollow space Y Y, to which chamber the said plate forms a light covering, excepting that space occupied by springs or screws L L, as before mentioned. I the centre of all the grooves and circles before described, is also the centre of the shaft. On the shaft I is fastened a plate or coupling Z, in which is inserted a bar F: this bar may be of any given breadth, but in depth must be less than the depth to which the circle E B was cut below the surface A B; to this bar is attached a wheel or roller G, shown in Fig. 3, upon a larger scale. The manner in which it is attached to the bar F is also there seen, and it is so attached to it that the top of the wheel or roller G shall always be higher than the top of the bar F. The wheel G, being attached to the bar F, will, when the bar is made to revolve, describe a circular



path H H H along the plain surface of the segments, before described. Let that portion of the plain surface of each segment which answers to the path of the roller G be rounded off, in such a manner as to

make that portion of the surface an arc of a circle, the convex circumference of which is presented to the roller G. In Fig. 3, at H, is shown a perpendicular view of one of the segments, rounded off in the manner described, and presenting its convex circumference to the roller G. There may, likewise, be another roller attached to the bar behind it, to lower down the segments in the same manner in which they are raised by the first roller. Now it is obvious, all the said segments being in their places in the groove C D, Fig. 1, that the roller G, in performing a revolution round the centre I, must travel along a series of convex arcs of circles, equal in number to the number of segments in the groove C D. The groove D E is, in fact, a recess in the deeper groove C D, and may, if necessary, be filled with hemp or tallow, or any other material which may answer the purpose intended.

"It must be remembered that Fig. 1 is a view of the underside of the machinery. Fig. 2 is a section of it, supposed to be in its proper position, resting as a cover to the circular chamber Y Y, and the segments resting upon a flat facing O O. Each segment projects over the facing O O on both sides; their projection on one side completes the cover over the hollow chamber, and the other is the rounded surface for the roller to lift them. The facing O O is exactly or as nearly as can be, level with the underside of the plate A B A B, when the plate is on its place, as represented in Fig. 2; so that when the segments are all in their places, they complete the semicircular chamber, and fit so close on their seats and in the groove, that were the chamber to be filled with any elastic fluid, they would prevent its escape, or nearly, excepting where the space is left for the springs or adjusting screws. The use of these segments, *which are what the patentee claims as his invention*, is as follows: conceive a door or valve to be fitted in the hollow chamber at Q, and a piston R, likewise fitted in the chamber so as to move round in it, and the bar F made fast to the piston, on the side and in the manner represented in Fig. 1; then, if an elastic fluid of sufficient strength enters the chamber at N, it will press equally against the door or valve, and the piston; but the door or valve being immoveable, and the piston moveable, the piston will be propelled forward in the circular chamber by the elastic fluid. The bar F being fastened to the piston, and the roller G to the bar F, in the manner represented in Fig. 3, and the roller being in motion with the bar and piston, the roller will lift the segments in succession, as it comes in contact with them. The segments before the bar, being by this means lifted, allow the bar to pass, and the operation being the same in all, the bar and piston make a complete revolution. Each segment, as soon as the bar leaves it, falls down by its own gravity, or by springs, or any other contrivance, so that the opening which is made for the bar to pass is closed before the elastic fluid reaches it; the elastic fluid being kept from the opening by the inner breadth of the piston exceeding the outer diameter of each segment. The door or valve is lifted out of the way of the piston, when the piston comes in contact with it, into the opening in the plate at N, a recess being made in

that segment which is opposite the door for that purpose; during which time the elastic fluid is shut out, but it enters again when the door returns to its seat, and thus the operation continues.

"In Fig. 2 C is the condensing vessel, *a* the air pump, *b* the air pump buckets, *d* the hot water cistern, *e* the clack. *f f*, the inclined plane for working the air pump bucket, is fastened in the shaft, and consequently revolves with it. To the air pump bucket is attached a hollow tube through which the shaft goes. To this tube is fastened a cross bar, at each end of which is a roller *r*, resting upon the inclined plane: of course when the plane revolves the bucket rises and falls. The plane is divided into two different angles, so as to make it more acute where the bucket rises, but nearly an angle of 45° where the bucket descends, as represented in the drawing. The injection enters the groove above the blocks, and keeps about three inches of water upon them: the injection then enters the condenser out of the groove, as seen at X. Each segment or block, K, is of sufficient weight to resist the pressure against that part of their under surface which is over the semi-circular chamber, and will generally be about five-eighths of an inch. The blocks may be likewise lifted exactly in their centre of gravity by means of a lever in the upper part of the groove, and worked by a roller or small inclined plane fastened to the shaft, as represented by the dotted lines; and as it is not necessary for the blocks to rise more than half an inch or five-eighths, the motion will be very easy; and whatever descending power the blocks have, they will propel the bar forwards proportioned to their weight and the space through which they move, so that there is only the friction of the blocks to overcome. Supposing the pressure on the piston to be 800 lbs. the weight of all the blocks will be about 500 lbs. for such a sized piston, and will seldom exceed more for the largest engines, as the space for the bar to pass will be nearly the same in all, the strength of the bar depending upon its breadth, not on its thickness: thus, 800 lbs. will move through the space of 16 feet, whilst 500 lbs. go through the space of half an inch: then, if the descending of the blocks is taken into consideration, as before described, the friction of the blocks will make no sensible difference to the progress of the piston. The lid M being the only opening into the engine, and the only stuffing-box, and that covered with water, no air can enter but what is contained in the water used for injection."*

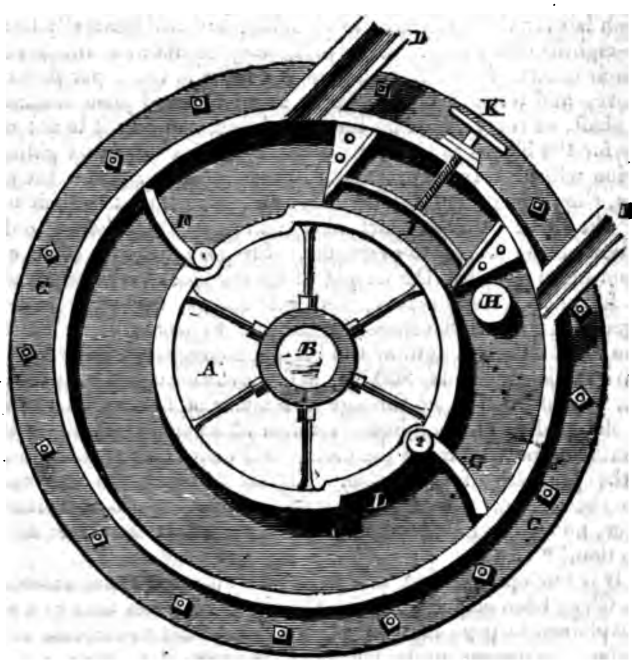
It is our opinion that this patent would never have existed had Mr. Clegg been acquainted with the effects of steam acting on a lever as explained at page 43. It is there shown that no increase of effect is gained by increasing the length of the lever; for although steam of a given pressure acts on a lever of two feet from the fulcrum with twice the effect it does on a lever of one foot, yet it is apparent that the consumption of steam is also doubled, and, therefore, that the power is as the steam consumed. Though it is presumed that this fact is too well known to need minute explanation, yet it is necessary now

* Specification of Patent.

to mention it, since there can be little doubt but that if Mr. Clegg had been aware of it, he never would have made use of those segments which alone constitute his patent; the purpose of such segments being (as has been explained) to obtain the effect of the steam in a channel at some distance from the centre of motion, without making use of the interior cylinder or plate, used in most of such engines.

No advantage, therefore, arises from the use of these segments; but, on the contrary, the extreme nicety of their fitting is a considerable drawback; and we apprehend also, that they would soon become deranged, and suffer the steam to escape. But the most objectionable part is the valve which has to be struck out of its place, whilst the piston is travelling at its full speed; indeed, there can be little doubt but that the rapid destruction of this valve was the cause of failure.

Mr. William Chapman's Rotative Engine, patented 1810, is represented by the accompanying drawing.



A represents a drum, packed on its two ends, and revolving within an exterior cylinder C C, so that a channel is formed between the two cylinders, in which the steam acts upon the flaps F G. I is a cavity filled with hemp, which effectually stops up the passage or channel; an adjusting screw K tightens up the packing as it wears; D is the steam pipe, and E the escape pipe. The steam being introduced at D presses upon the valve or flap F, which recedes from the

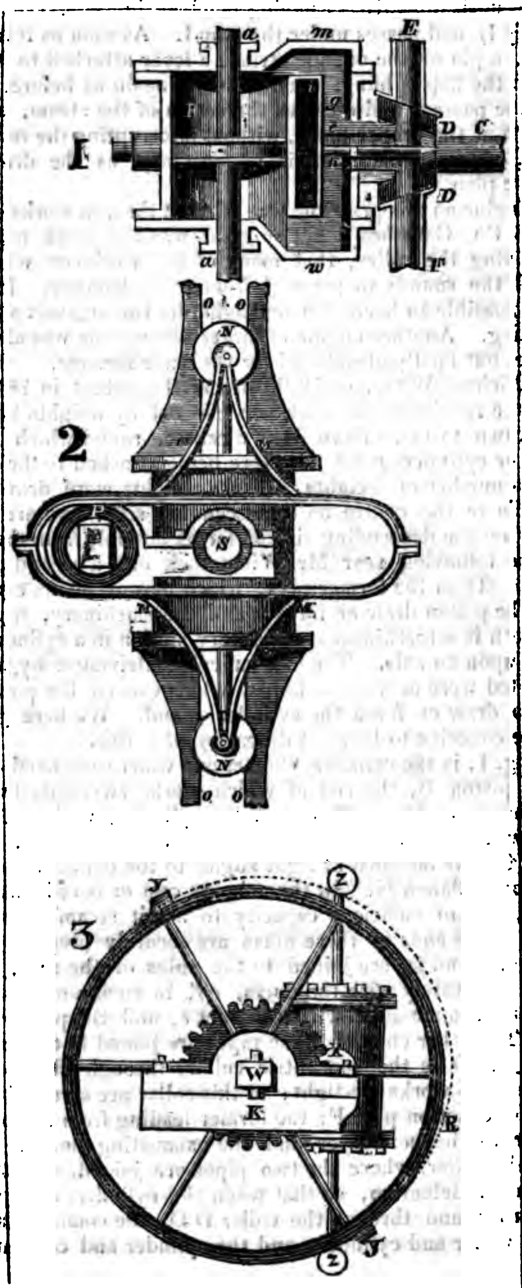
pressure, until the valve G having reached the roller H, is shut into the cavity L, and passes under the stop I. As soon as it has cleared the stop, a pin on the outside strikes a lever attached to the spindle on which the flap is hung, opening it out again as before, so that it fills up the passage and receives the action of the steam, allowing F to be shut at the proper place, without interrupting the revolution of the axle. More explanation is unnecessary, as the drawing fully shows the plan.

An engine on this principle was tried at the iron works of Messrs. Hawks & Co. Gateshead, but so great was the noise made by the flaps striking the roller, that many of the workmen who heard it imagined the sounds to proceed from a tilt hammer. It was also found impossible to keep it steam tight, by the greatest attention to the packing. Another engine of larger dimensions was also tried on the Tyne, but finally abandoned for the same reasons.

Mr. Richard Witty, of Hull, procured a patent in 1810, for an engine, the revolution of which was effected by weights being alternately drawn to and driven from a centre, round which a working cylinder or cylinders revolved, there being attached to the piston rod or rods a number of weights. These weights were drawn as near as possible to the centre on the ascending side, and are projected outwards on the descending side as far as possible from the axis.

In the following year Mr. Witty took out a second patent for improvements on the former plan, which improvements consisted in making the piston draw or force round the machinery, whilst itself moved both in a rectilinear and rotatory motion in a cylinder; which revolved upon an axis. The mechanical contrivances by which this was effected were of various kinds, which caused the power of the piston to draw or force the cylinder round. We here give those which we conceive to be most deserving of notice.

A, Fig. 1, is the cylinder, shorter and wider than fixed cylinders, with its piston B, the rod of which works air-tight, through the stuffing boxes *a a*, at each end of the cylinder, with a provision at *w* to blow the air and water at starting when required. The axis or shaft, C C, is fastened at right angles to the cylinder, with screw bolts through flanch *i i*. In the axis are cast or bored two ducts or channels, *e f*, of sufficient capacity to admit steam to supply the cylinder. The ends of these ducts are securely plugged up. The side pipes, *h* and *g*, are joined to the sides of the axis, and communicate separately with the ducts, *e f*, in such a manner that the pipe *h* shall communicate with the duct *e*, and the pipe *g* with the duct *f*. The other ends of these pipes are joined to the ends of the cylinder. D D is the concentric collar, through which the taper part of the axis works air-tight; to this collar are screwed the steam pipe E and eduction pipe F; the former leading from the boiler, and the latter to the condenser and the exhausting pump. The two holes in the collar, where the two pipes are joined, are made in the form of a parallelogram, so that when the cylinder, side pipes, and shaft, turn round through the collar D D, the communications betwixt the boiler and cylinder, and the cylinder and condenser, will


1
2
3
W
K
R
S
P
E
D
C
F
N
O
Y
Z

be open alternately during half the revolution, and each side of the piston will be open, or exposed alternately to the steam and the condenser.

Fig. 2 represents what is called the cardinal motion, attached to the engine. It consists of a parallelogram, frame, or trammel groove, joined to the piston rod by the two triangles M M, M M. The two friction wheels, N N, are hung betwixt the ends of these triangles, and the piston-rod and rim betwixt the side joints *o o o o*, cast or screwed upon the covers of the cylinder. At the distance of half the stroke of the piston from the centre of the cylinder shaft is fixed a strong stud or pin, having a strong knee crank, at right angles from it, to support the gudgeon end of the cylinder shaft at S. On the round part of this stud runs a wheel P, filling the trammel groove, and the square is driven tight into another piece of cast-iron, and keyed fast, and this is bolted down to a beam of wood, as at K, Fig. 3. When the steam is admitted under the piston the trammel groove moves with the piston rod, and is turned from a rectilinear to a rotary direction by the stud P, resisting on one side of the trammel, and causes the cylinder to revolve towards the stud, and as it revolves the groove comes perpendicular, or at right angles, to the situation in which it is seen in the figure, the cylinder lays horizontal, the piston is at the extremity of its stroke, and the alternations of the steam take place at that instant in the axis. In this position the engine may be said to be passing centres, similar to that of a beam engine, when passing the vertical position of the crank; and thus a continued revolving of the cylinder is effected, while its piston describes a circle, the diameter of which is half the length of the stroke.

Fig. 3 is a contrivance for applying the force of the piston upon a wheel R, or crank, which revolves upon a separate axis at W, placed half the length of the stroke of the piston from the centre of the cylinder shaft X, which is supported by a knee from or through the centre of the wheel, similar to the contrivance for supporting the gudgeon or cylinder, Fig. 2. The diameter of the wheel is made equal to the length of the piston rod; and has its rim made to incline or project, in order that the piston rod may lay hold of it alternately at the stops *y y*.

On inspecting the first invention, namely, the method of obtaining a revolving motion by the projection of weights, it appears to us that Mr. Witty has quite mistaken the object which engineers have had in view in their attempts to obtain a rotative engine. It will by this time be seen that the object was principally to avoid the waste of effect by giving motion to a mass of matter, and bringing it to rest at each movement of the piston of a steam engine. It will also be seen that these weights (the particular position of which constitutes the power of Mr. Witty's engine) have to be moved and brought into rest, exactly in the same manner as those parts of a steam engine whose motion causes the inconvenience complained of. The same objection, therefore, applies to his in a tenfold degree, for the common engine has only to overcome the inertiæ of such a quantity of

material as may be necessary for sufficient strength; but here the power being as the weight, the inconvenience sustained by reciprocation in engines of large powers will be readily conceived.

Mr. Witty's improved method, in which he dispenses with the weights, displays considerable ingenuity. It cannot, however, be properly called a rotative engine, because the steam does not act upon piston, vane, or any thing whose motion is rotative: his invention is merely a new way of applying the action of a common piston. The best mode, therefore, of appreciating its merit is by comparing it to a cranked engine, and in doing this we shall endeavour to show its inferiority.

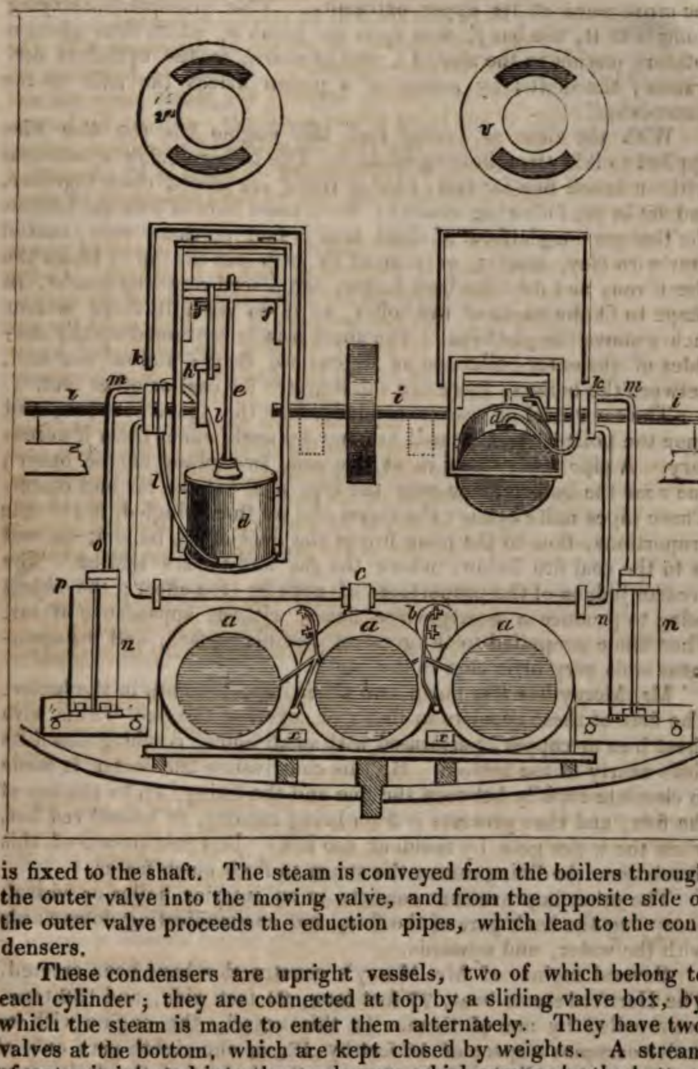
The patentee states its advantages to consist in saving power lost by reciprocation, and in dispensing with a fly wheel. To the first it may be said, that although the beam and some of its appendages are not necessary, yet the increase of the friction by the use of a grooved frame; the danger of bending the piston rod by its oblique application in forcing round the engine, are greater inconveniences than those attendant on a beam; to this it may be added, that, when a crank is used, there are two points where the crank receives its impulse at right angles to the direction of the force, and is impelled in the same line with the piston, which is of course the most advantageous application of its power; but in no part of the revolution of this engine, in any of its modifications, does the impulse come much nearer the direction of the produced motion than an angle of 45°.

Nor do we think that a fly wheel can be dispensed with. It being quite evident that the different degrees in the obliquity of its direction must render a fly wheel absolutely necessary to produce an equable motion.

On this principle is the Revolving Engine of Mr. Samuel Morey, now used in several American steam boats. As there is considerable novelty in the mode of generating the steam we apprehend its insertion will not be considered unnecessary.

a a a are the steam boilers; *b b* the tar vessels, to be afterwards described; *c* the valve box; *d d* the two revolving cylinders, shown in different positions; *e e* the piston rods; *f* the 'pitman'; *h* the centre piece; *i i* the shaft; *k k* the valves; *l l* the steam pipes; *m m* the escape pipes; *n n* the condensers; *v v* the face of the valves, shown in separate figures; *x* the tar fire.

The frame, which holds the cylinders *d d*, is suspended by its opposite sides so as to revolve. The centre piece *h* acting as a crank, is fixed to the end of the shaft *i*, projecting over the cylinder, and from this centre piece the bar or pitman *f* communicates with the cross piece of the piston rod. Two circular pieces or valves *k*, one of brass and the other of iron, are placed on the same axis *i*, but on the outside of the frame; one of them being fixed to the axis, and the other accompanying the frame and cylinder in their revolution. From this last valve proceed the pipes *l l*, which conduct the steam to each end of the cylinder. The valve has a smooth face, which is kept close by springs to the face of the other valve, which



is fixed to the shaft. The steam is conveyed from the boilers through the outer valve into the moving valve, and from the opposite side of the outer valve proceeds the eduction pipes, which lead to the condensers.

These condensers are upright vessels, two of which belong to each cylinder; they are connected at top by a sliding valve box, by which the steam is made to enter them alternately. They have two valves at the bottom, which are kept closed by weights. A stream of water is injected into the condensers which escapes by the bottom valves *p p*, by which, also, the air is blown out at every stroke; in this manner the engine is at first cleared of air.

In order to give a reversed motion to the engine, two cocks and cross pipes are employed, for the purpose of changing the passage of the steam to the opposite sides of the valves.

When the engine is thus constructed, the steam admitted below the piston by the lower pipe *l*, forces up the piston rod *e*, and

the cross piece at its upper extremity. This crosspiece carrying along with it, the bar *f*, acts upon the crank *h*, which thus gives a rotatory motion to the shaft *i i*, and of course to the cylinders and frames; the shaft *i* by means of a pinion drives the axis of the water-wheel.

With the view of saving fuel, this engine has the *Gas Fire* applied to it in the following manner: The boilers being cylindrical with an inside flue for fuel, two or three are placed close together, and set in the following manner; first, cross bars of iron are laid on the timbers; a platform of sheet iron is laid on these bars, coated over with clay, mortar, or cement to keep out the air. Upon the sheet iron, and over the bars below, are placed cast iron blocks, in shape to fit the curve of the boiler, so as to raise it three or four inches above the platform. The sheet iron is continued up the outsides of the outer boilers so as to enclose them; and at one end, between the boilers, there are small grates for coal or other fuel.

The tar vessel or vessels are lodged in the space between, and upon the boilers, and a small fire may be made under them if necessary. A pipe leads steam in at one end, two pipes at the other; one near the bottom, one near the top, lead out the tar and steam. These pipes unite below; the steam and tar thus mingled, in suitable proportions, flow to the plain fire or the flues of the boilers, as well as to the coal fire below, where the gas and tar are ignited. The fireman judges of the proportions of each by the effect; the object being to produce a nearly white flame, without appearance of tar. Thus flame is applied to the greatest possible surface, and the apparatus adds very little cost to the engine.

Mr. Morey has also made two other improvements in the boiler. The first of these consists in lining or covering the flue within with sheet iron or copper, perforated with small holes, reaching down its sides nearly to the bottom. By this contrivance the water is made to circulate rapidly between the flue and the lining, up to the top of the flue, and thus protects it from being run dry, or heated red hot, when the water gets by accident too low. In consequence of this circulation, the lining causes the steam to form much faster.

The other improvement consists in an interior boiler or vessel, occupying the back part of the flue, and communicating downwards with the water, and upwards.

Several engines of Mr. Morey's construction have been erected. The Hartford steam boat, 77 feet long, 21 feet wide, and 136 tons, is propelled by one of them. In this vessel, the engine with its boiler occupies a space of 16 feet by 12, or one-eighth part only of the boat; the cylinders being hung in the timbers of the deck; over the boilers. The two cylinders are 17 inches each in diameter, and have a stroke of 18 inches, and revolves 50 times in a minute. The area of the piston being about 227 inches, it will, when worked with steam of 50 lbs. have the power of 100 horses.

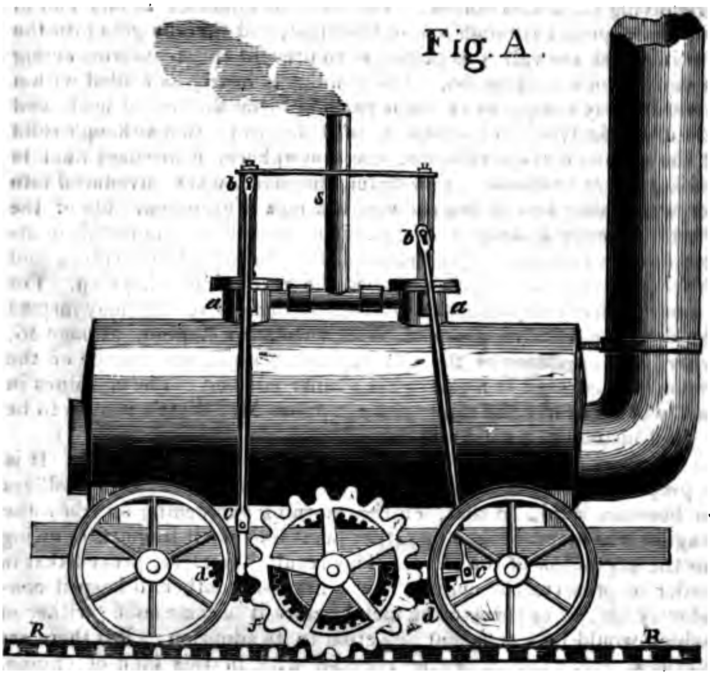
The Rotative Engine of Mr. Onions, of Bristol, patented 1812, differs essentially from all we have described. The invention consists of an annulus or hollow ring connected by hollow arms, with

a revolving shaft also hollow. The steam is admitted at one end of this shaft, passes through one of the arms, and thereby gets into the rim in which are valves so placed as to prevent the steam from acting in more than one direction. The annulus is nearly half filled with a metallic alloy composed of eight parts of bismuth, five of lead, and one of quicksilver. The property of this alloy is, that although solid at the common temperature of the atmosphere, it becomes fluid in boiling water or steam. The steam, therefore, when introduced into the wheel after first fusing the alloy, forces it up on one side of the wheel, thereby making it heavier than the other: the metal, in attempting to regain its equilibrium, causes the wheel to revolve; and the supply of steam being continued the revolution is kept up. For a more perfect comprehension of this machine our readers may inspect the drawing we have given of Watt's Rotative Engine, at page 46, where the operation of the valves, and entrance and escape of the steam, are effected in a somewhat similar manner. The machines in fact will be nearly the same, if we suppose Mr. Watt's weight to be a fluid instead of a solid one.

A singular mishap befel this machine on its first trial. It is a property of bismuth that, like water, it expands as it crystallizes or becomes solid, so that, on the morning succeeding its trial, the engine was found broken or rather burst into small fragments, owing to the expansion of the alloy. This result, therefore, proved that in order to preserve the engine, it was necessary either to keep it constantly hot, or to remove the metal before it became solid; either of which would be a sufficient objection to its adoption. But there are besides, other difficulties to contend with in this kind of engine, which we shall notice in our remarks on Masterman's Steam Wheel.

A short description of Trevithick's Loco-motive Engine was given at page 110. It appears that the more general adoption of this machine was prevented by a fear that the wheels would not adhere sufficiently to the surface over which it passed, but that they would slip round without producing loco-motion when any tolerable load was attached to the machine. To obviate this *imagined* difficulty Mr. Blenkinsop, of Middleton Colliery, near Leeds, obtained a patent in 1811, for the application of a rack or toothed rail laid down on one side of the railway from end to end. Into this rack a toothed wheel is worked by the steam engine: the revolution of which wheel produces the necessary motion without any of the *slipping* alluded to.

The accompanying figure will convey to our readers an idea of Mr. Blenkinsop's plan. The boiler *x* is placed on a wooden or cast-iron frame *y*. Through its interior passes a wrought-iron tube of sufficient diameter to hold the fire and grate; this tube is carried out at the further end of the boiler, when it is bent upwards and continued sufficiently high to form the chimney *z*. *a a* are two working cylinders fixed in the boiler, and which work in the usual way; the piston rods are connected by cross heads to the connecting rods *b b*. These connecting rods are brought down on each side of the boiler and there joined to the cranks *c c*, (there being corresponding cranks on the other side of the machine) which are placed at right angles to



each other, consequently the two cranks on the first shaft are horizontal and at their greatest power, at the time the other two are passing the centre. Upon these shafts are fixed (under the boiler) two small toothed wheels, which give motion to a larger toothed wheel *e*, fixed upon a third axle. A toothed wheel, *f*, is firmly keyed to the end of the central axle, and revolves with the wheel *e*. The teeth of *f* correspond with, and work into a rack, R R, stretched along one side of the railway. Motion, therefore, is given by the pistons to the wheels *d d*, which they communicate to the wheel *f* by *e*: a progressive movement is given to the carriage by the teeth of *f* taking hold of the rack.

By this means the load can be drawn up a greater acclivity than by the machine of Messrs. Trevithick and Vivian, the only objection being that the power is applied on one side only, which must have a tendency to force the flanges or projecting rims of the supporting wheels, against the edges of the rails, by which an extra friction would be produced. This, however, is a trifling inconvenience, and is not found in practice to deduct much from the effect of the engines, several of which have, since the date of the patent, been in constant use in drawing coal waggons between Middleton Colliery and Leeds.

In the year 1813 Mr. William Brunton, of Butterly Iron Works, also obtained a patent for a mode of giving motion to carriages by a very novel contrivance.

The present engraving represents this Loco-motive Engine, which he terms his "*mechanical traveller*." "The boiler is nearly similar to that of Mr. Blenkinsop's semi-circular *(circular)*; there was a tube passing through it to contain the fuel." The cylinder A was placed on one side of the boiler; the piston-rod is projected out behind horizontally, and is attached to the leg *a b*, at *a*, and to the reciprocating lever *a c*, which is fixed at *c*; at the lower extremity of the leg *a b*, feet are attached by a joint at *b*; these feet lay a firmer hold upon the ground, being furnished with short prongs, which prevent them from slipping, and are sufficiently broad to prevent their injuring the road.

Fig. B.

On inspecting the drawing it will be seen that when the piston rod is projected out from the cylinder, it will tend to push the end of the lever or leg *a* from it, in a direction parallel to the line of the cylinder; but as the leg *a b* is prevented from moving backwards, by the end *b* being firmly fixed upon the ground, the re-action is thrown upon the carriage, and a progressive motion given to it, and this will be continued to the end of the stroke. Upon the reciprocating line *a c* is fixed at 1, a rod, 1, 2, 3, sliding horizontally backwards and forwards upon the top of the boiler; from 2 to 3 it is furnished with teeth, which work into a cog wheel, lying horizontally; on the opposite side of this cog-wheel a sliding rack is fixed, similar to 1, 2, 3, which, as the cog wheel is turned round by the sliding rack, 2, 3 is also moved backwards and forwards. The end of this sliding rod is fixed upon the reciprocating lever *d c*, of the leg *d e*, at 4. When, therefore, the sliding rack is moved forwards in the direction 3, 2, 1, by the progressive motion of the engine, the opposite rod 4, is moved in the contrary direction, and the leg *d e* is thereby drawn towards

the engine; and, when the piston rod is at the farthest extremity of the stroke, the leg *d e* will be brought close to the engine; the piston is then made to return in the opposite direction, moving with it the leg *a b*, and also the sliding rack 1, 2, 3; the sliding rack acting on the toothed wheel, causes the other sliding rod to move in the contrary direction, and with it the leg *d e*. Whenever, therefore, the piston is at the extremity of the stroke, and one of the legs is no longer of use to propel the engine forward, the other, immediately on the motion of the piston being changed, is ready in its turn, to act as a fulcrum or abutment for the action of the moving power, to secure the continual progressive motion of the engine.

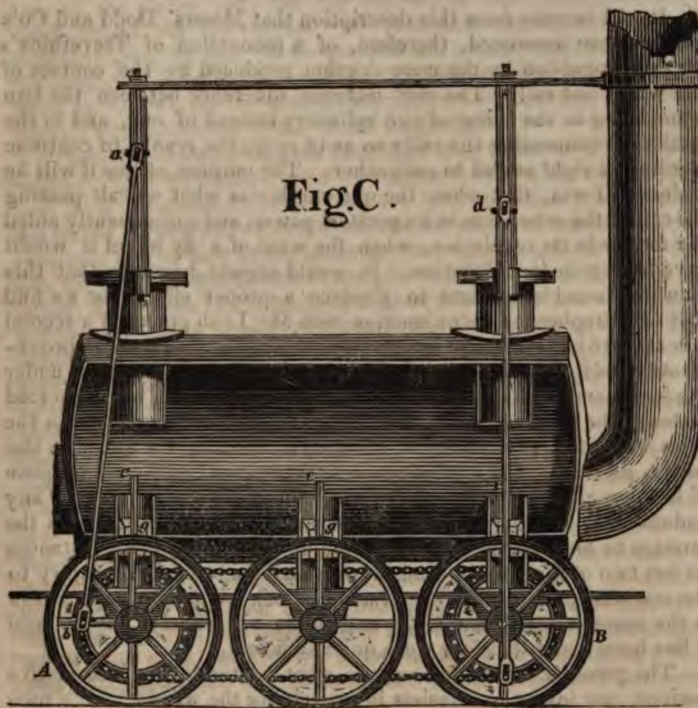
The feet are raised from the ground during the return of the legs towards the engine, by straps of leather or rope fastened to the legs at *f f*, passing over friction sheeves, moveable in one direction only, by a ratchet and catch worked by the motion of the engine. The feet are described of various forms in the specification, the great objeet being to prevent them from injuring the load, and to obtain a firm footing, that no jerks should take place at the return of the stroke, when the action of the engine came upon them; for this purpose they were made broad, with short spikes to lay hold of the ground.*

The next attempt we find to produce a loco-motive steam engine is in the patent of Messrs. Dodd and Stephenson, of Newcastle upon Tyne, a description of which we extract from Mr. Wood's work on rail roads. The patent was dated February 28, 1815, and consisted of the application of a pin upon one of the spokes of the wheels that supported the engine, by which it travelled upon the rail road, the lower end of the connecting rod being attached to it by what is termed a ball and socket joint; the other end of the connecting rod being attached to the cross-beam, worked up and down by the piston.

a b represents the connecting rod, the end *a* attached to the cross beam, and the end *b* to one of the spokes of the wheel; in like manner the end *d* of the connecting rod *c d*, is attached to the beam of the other piston, and *h* and *c* to a pin fixed in the spokes of the wheel B. By these means, the reciprocating motion of the piston and connecting rod is converted by the pin upon the spokes acting as a crank into a rotatory motion, and the continuation of this motion secured by the one pin or crank being kept at right angles to the other, as shewn in the drawing.

To effect this, the patentees had two methods to crank the axle on which each of the wheels were fixed, with a connecting rod between, to keep them always at the angle, with respect to each other; or to use a peculiar sort of endless chain, passing over a toothed wheel on each axle. This endless chain which is now solely used upon these kind of engines, consisted at first of one broad and two narrow links, alternately fastened together at the ends with bolts; the two narrow links were always on the outside of the broad link; consequently, the distance they were separated laterally would be equal to the breadth of the broad link, which was generally about

* Wood on Rail Roads.



two inches, and their length three inches. The periphery of the wheels fixed upon the axles of the engine, were furnished with cogs, projecting from the rim of the wheels, (otherwise perfectly circular and flat) about an inch or one and a half inches. When the wheel turned round, these projecting cogs entered between the two narrow links, having a broad link between every two cogs, resting on the rim of the wheel; these cogs, or projections, caused the chain to move round with the wheel, and completely prevented it from slipping round upon the rim. When, therefore, this chain was laid upon the two toothed wheels, one wheel could not be moved round without the other moving round at the same time with it; and thus secured the proper angles to the two cranks.

This mode of communicating the action of the engine, from one wheel to another, is shewn in the drawing; the wheels A and B having each projecting cog wheels, round which the endless chain passes. This contrivance entirely superseded the use of the cog wheels, and were without the jolts or jerks incident to them; for, when the chain got worn by frequent use, or was stretched, so as to become too long, one of the chains of the axles could be moved back to tighten it again, until a link could be taken out, when the chain was moved back again to its former situation.

It will be seen from this description that Messrs. Dodd and Co's improvement consisted, therefore, of a renovation of Trevethick's plan of propulsion by the mere friction produced by the contact of the wheel and rail. The only material difference between the two plans being in the using of two cylinders instead of one, and in the method of connecting the axles so as to cause the cranks to continue working at right angles to each other. The purpose of this it will be understood was, that when the one crank was what we call passing the centre the other was at its greatest power, and consequently aided the former in its revolution, when for want of a fly wheel it would have to stop in that situation. It would appear however that this plan was found insufficient to produce a proper effect, for we find that Mr. Stephenson in conjunction with Mr. Losh procured a second patent in 1816, for some improvements upon it. These improvements consisted in the application of steam cylinders placed under the boiler and upon the axles of the wheels : into which were inserted pistons, the rods of which were attached to bearings wherein the axles worked. These pistons being acted upon by the steam in the boiler, performed the part of springs and served the double purpose of keeping all the wheels pressed upon the rails when owing to any undulations, there would otherwise have been a tendency in the carriage to have rested only on three, or perhaps in some instances on but two of the wheels, and of preventing any material injury to the machinery by jolts. The drawing which we use for explanation is the same as Dodd and Co's, and shews six wheels, but by trial it has been found that four were quite sufficient.

The patentees state that :—"in what relates to the loco-motive engines, our invention consists in sustaining the weight, or a proportion of the weight of the engine upon pistons, moveable within cylinders, into which the steam or water of the boiler is allowed to enter, in order to press upon such pistons ; and which pistons are, by the intervention of certain levers and connecting rods, or by any other effective contrivance, made to bear upon the axles of the wheels of the carriage, upon which the engine rests.

e e e shew the cylinders placed within the boiler, one side of which, in the drawing, is supposed to be removed, to expose them to view. They are screwed by flanges to one side of the boiler, and project within it a few inches ; and are open at the top, to the steam or water in the boiler ; *g g g* are solid pistons, filling the interior of the cylinders, and packed in the common way to render them steam-tight. The cylinders in the figure are drawn as cut through the middle to shew the pistons. The cylinder is, also, opened at the bottom, and is screwed upon the frame of the engine, as represented at *a a*, Fig. 2. The pistons are furnished with a rod, in a similar way to other pistons, inverted and securely fixed to it ; the lower end of which passes through a hole in the frame which supports the engine, and presses upon the chain which rests on the axis of the wheels on which the carriage moves. The chain has liberty to move up and down with the piston rod. When, therefore, the steam presses upon the piston, the weight is transmitted to the

axle by the piston rod, and the reaction of that pressure takes as much weight off the engine. If, therefore, the cylinders are of sufficient area, so that the pressure of the steam upon the whole of the pistons is equal to the weight of the engine, the engine will be lifted up, as it were, or entirely supported by the steam, which thus forms a kind of spring of the nicest elasticity.*

These loco-motive engines have been long in use at Killingsworth colliery, near Newcastle, and at Hetton Colliery, on the Wear, so that their advantages and defects have been sufficiently submitted to the test of experiment; and it appears that, notwithstanding the great exertions on the part of the inventor, Mr. Stephenson, to bring them into use on the different rail-roads now either constructing or in agitation, it has been the opinion of several able engineers, that they do not possess those advantages which the inventor had anticipated; indeed, there cannot be a better proof of the doubt entertained regarding their utility than the fact, that it has been determined that no loco-motive engines shall be used in the projected rail road between Newcastle and Carlisle, since, had their advantages been very apparent, the persons living immediately on the spot in which they are used, namely, Newcastle, would have been acquainted with them.

The principal objections appear to be the difficulty of surmounting even the slightest ascent; for it has been found that a rise of only one-eighth of an inch in a yard, or 18 feet in a mile, retards the speed of one of these engines in a very great degree, so much so, indeed, that it has been considered necessary, in some parts where they are used, to aid their ascent with their load by fixed engines, which drag them forward by means of ropes coiling round a drum. The steam cylinders below the boiler, which *constituted* the patent, were found very defective, for, in the ascending stroke of the working piston they were forced inwards by the connecting rod pulling at the wheel in turning itr ound, and in the descending stroke the same pistons were forced as much outwards; this motion or play rendered it necessary either to increase the length of the working cylinders as much as there was play in the lower ones, or to incur the danger of breaking or seriously injuring the top and bottom of the former by the striking of the piston, when it is forced too much up or down. As our meaning may not be fully comprehended without elucidation, let us imagine the cylinder of a common beam engine to be set upon springs, which have a play of one foot: the weight of the cylinder, when at rest, depresses the spring six inches, but if the engine be put in motion, *then* as the piston ascends and gives motion to the machinery, the springs below the cylinder being, as it were, the abutment upon which the steam acts, are forced downwards against their seat, with precisely the force that the piston exerts in overcoming the resistance of the machinery. In like manner when the piston descends, as much weight or pressure will be taken off these springs by the same means. The cylinder would, therefore, vibrate or dance upon the bearing springs; and, as

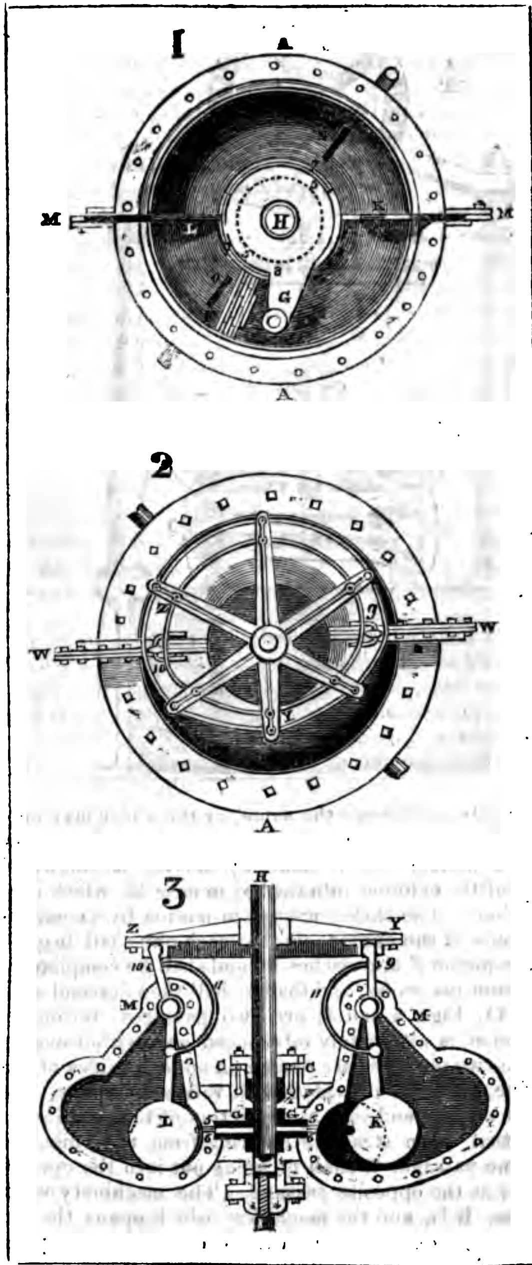
* Wood on Rail-roads.

the motion which it thus obtains is the reverse of the motion then given to the piston, the length of the cylinder should be lengthened to allow for the extreme vibration to which it is liable. A quantity of steam would therefore be lost in filling up this extra length of the cylinder at each stroke. This would also happen if the cylinder were *fixed* as usual, and the carriages of the crank and fly wheel supported upon springs, and this arrangement would then be exactly the same in principle and effect as the parts of the loco-motive engine to which we now allude.

Mr. Trevithick's patent of 1815 is introduced a column or ring of water, which running round the piston renders the whole air-tight. By this means he avoids a great proportion of the usual friction, a very moderate degree of tightness in the packing, being in practice found sufficient to prevent the passage of so dense a fluid as water. The second part of this invention consists in causing steam of a high temperature to spout out against the atmosphere, and by its recoiling force to produce a motion in a direction contrary to the issuing stream, similar to the motion produced in a rocket wheel, or to the recoil of a gun, by which means a rotative action is produced. Mr. Trevithick also describes three other improvements on the high-pressure engine, the latter of which, though only applied to nautical purposes, is by far the most important. It consists in employing a spiral worm or screw, similar to the vanes of a smoke-jack, which, being made to revolve at the head or stern of the vessel, produces the required motion.

Mr. Turner's Rotative Engine, patented in 1816, displays extraordinary ingenuity and excellence; we therefore give a more enlarged account of it from the specification than of most other such inventions.

"Fig. 1 is a plan of the engine, represented as if opened to show the internal structure. Fig. 2 is another plan, Figs. 3 and 4 are sections, taken through the axis of the engine in different directions, to show the internal parts. A A, B B, C C, is the cylinder or external case of the engine, made in two or more parts, which are fastened together with screws, so as to form a circular or annular passage, the transverse section of which is likewise circular, as shown at E E, Figs. 3 and 4; the piston F, Fig. 1, is accurately fitted into this circular passage, and is caused to revolve therein by the pressure of the steam, which is applied behind it or on the side F, whilst a vacuum is made before it, or on the side G. The piston being connected with a central plate G, which is fixed fast upon the axis or shaft H; the said shaft is put in motion, and by wheel work I, or other machinery which is best adapted, the power of the engine is communicated to any useful purposes to which it is intended to be applied. The means by which the force of steam is made to produce the rotatory motion is as follows: two valves or sliders, K and L, are applied at the opposite sides of the annular passage or cylinder, E E, in the manner represented in Figs. 1 and 3. The edge of the central plate G, which has the projecting arm to communicate with the piston, must be made so that they can be made to shut up the passage of the cylinder, E E, as represented at L, and prevent the


1
A
M
H
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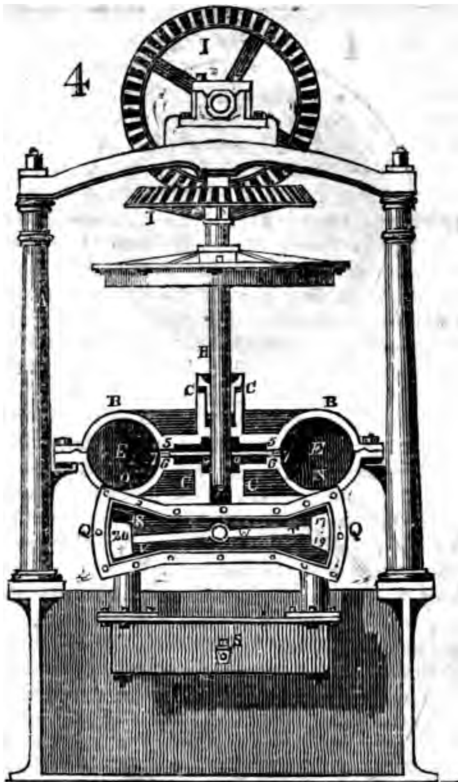


passage of the steam through the same, or the slider may be opened, as shown by the dotted lines, to allow the piston F to pass freely through the cylinder; this is done by moving it sideways on its centre 3 out of the cylinder into the box or case M, which is provided for its reception. The sliders are put in motion by a communication from the outside of the engine, so that each one shall begin to open as soon as the piston F approaches it, and shall be completely opened whilst the piston passes by, and that it shall then descend again upon its seat. N O, Figs. 1 and 4, are two passages, through each of which the steam is alternately introduced and withdrawn from the cylinder; the two passages are placed on opposite sides of the centre of the engine, and are provided with valves or cocks, which are adapted to be opened and shut by the action of the machinery in such succession, that when steam is entering from the boiler, into the cylinder at one passage, it shall be going out into the open air or to the condenser at the opposite passage. The machinery which actuates the slides, K L, and the machinery which opens the valves for the admission and exhaustion of the steam through the passages N

and O, acts in concert with each other, and also with the motion of the piston F, so that, as soon as possible after the piston has passed by the seat of a slider, the same shall be lowered down into its place ready to close the passage of the cylinder behind the piston, and the instant the piston has passed by the next opening the steam is admitted to flow therein, and act between the slider and the piston, to force the same forwards in the cylinder by its expansive force. To explain the action of the engine more clearly, suppose the parts in the position of Fig. 1; the slider L is shut, and the steam is flowing through the passage O into the space between the slider L and the piston F, at the same passage N is open to the condenser, to exhaust the steam from the remaining part of the cylinder, and remove the pressure from the front side G of the piston. In consequence, the pressure of the steam acting behind the piston of the side F, puts the same in motion in the direction of the arrow, and drives the arm of the central plate before it. The slider K, now in the act of opening, and by the time the projecting part of the plate G arrives at its seat, it wiil be quite open into the box M, where it will remain until the piston F has passed by its seat; it then begins to descend, and by the time the piston arrives at the opening of the passage N, the slider K will be completely shut and stop the cylinder. The instant the piston has passed over the opening of the passage N, the steam valves are changed by the machinery, so as to admit the steam into the passage N, and also to allow the steam to pass away through the other passage O to the condenser; in consequence the steam enters the space between N and K, and thus, being behind the piston, drives it still forwards towards the slider L, which immediately begins to rise by the action of the machinery, and as soon as the projecting part G of the central plate approaches it, it will have retreated into the box M, leaving the cylinder free for the passage of the piston. Immediately after the piston has passed the slider, L descends again, and gets settled to its place by the time the piston arrives at the opening O; and the instant the piston has passed over this opening the steam valves are changed again, so that the steam will be admitted at O behind the piston, and act between the slider L and the back of the piston to force it forwards, which is the same position represented in the figure. By this means the pressure of the steam is always made to act behind the piston, and the vacuum is made before the same. The sliders K and L are put in motion by levers 9 and 10, which are fitted on the outsides of the boxes M, but move upon the same centre pins 3, as the sliders move upon within side the boxes, the levers being forked, as shown at Fig. 5, to reach on each side of the boxes, and the centre pins 3 pass through the sides of the boxes, and also through both forks of the levers 9, 10, but do not turn round in the holes. To communicate motion from the levers at the outsides of the boxes to the valves withinside, curved rods, 11, 11, are carried from the levers through the sides of the boxes M, and jointed to the arm of the sliders; stuffing boxes are formed round the rods to make tight fittings where they pass through the sides of the boxes M; the ends of the levers, 9, 10, are made to be included

is an eccentric groove or rein Z Y, fixed to the central axis H; the form of this is shown in Fig. 2, and is such as to hold sliders shut, except during the time that it is necessary to lift up the same to allow the piston to pass by. To make the sliders fit steam-tight when they are shut, they are made rather larger than the diameter of the cylinder, and are received in grooves made round in the inside thereof, and the valves are ground against one of these faces of each of these grooves, so that they will fit tight without any packing. The piston is made of several segments put together, with springs behind them to throw them out against the inside surface of the cylinder, and it is thus made tight without any packing of hemp.

"The edge of the central plate G, which has the projecting arm to communicate with the piston, must be made to fit tight between the upper and lower halves which compose the cylinder, so as to prevent the escape of steam between them, and at the same time leaving the said plate freely at liberty to revolve in the space; for this purpose the edge of the plate is surrounded by two rings of brass, 5 and 6, which are laid one upon the other with springs between them, so as to throw them against the upper and lower surfaces of the central space, to which they are accurately fitted by grinding; these rings extend round rather more than half the circumference of the plate G, and are attached thereto by a joint pin 7, Fig. 1, which causes them to revolve with it; but they require no other fastening, as the pressure of the steam will keep them in their places.

"To prevent the escape of the steam through the opening or division between the two rings 5 and 6, a third ring, 7, 8, fitted to them, cover the joints, and the external edge of this which is made round or semi-circular like a bead, is received into corresponding notches made in the edges of the sliders, and thus to make a fitting between the edges of the sliders, when the same are closed, and the edge of the moveable central plate. The valves which are to admit alternately the steam into the passage N O, may be constructed in the same manner as the valves for the ultimate supply of the upper and lower part of the cylinder of any common steam engine; but the most convenient manner of doing this is shown in Fig. 4, Q Q, is an iron box, into which the steam from the boiler is admitted; this box is fixed beneath the cylinder of the engine; 17, 18 are two openings from which curved tubes proceed upwards to the openings N O of the cylinder; there are also two other openings, 19 and 20, which turn downwards with crooked tubes to the condenser S. T V are boxes or cups fixed at the opposite ends of a lever T W V, of which W is the centre of motion; the boxes or cups are intended to cover the openings, in the manner represented by the figure, and the faces or edges of the boxes are ground to fit close upon the flat plate or surface, in which the openings 17 and 18 are made. When the box T is up, as in the figure, it covers the two openings, 17 and 19, so as to connect them together, and therefore the steam in the cylinder will be drawn off through 17 and 19 to the condenser; at the same time the box V at the opposite end of the lever is drawn, and in this position the box leaves the opening 18 uncovered, so that the steam

with which the box is filled will have free passage into the cylinder; by moving the lever T V on its centre W, sufficiently to raise up the box V, and depress the other T, the action will be exactly reversed, viz. the box V will connect the openings 18 leading from the cylinder at the opening 20, which leads to the condenser; and the opening 17 will be uncovered, so as to admit the steam from the box through it into the cylinder at the opening N."

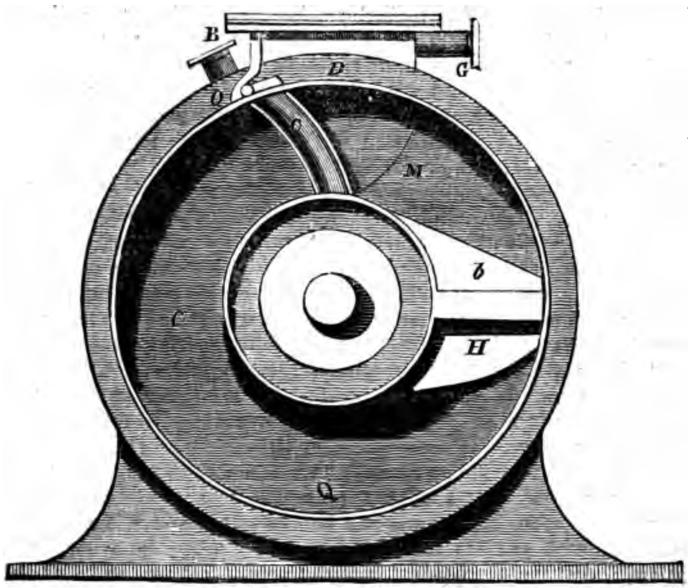
There is great ingenuity displayed in the formation of this machine, and the whole shows much mechanical ability; nevertheless there are defects of a sufficiently prominent nature to account for its failure. The very common fault of great friction, arising from the use of the revolving plates, is here a difficulty which we conceive could not be readily overcome; but the principal cause would be leakage, arising from the impossibility of keeping the rubbing surfaces steam-tight. This leakage would take place principally in the part where the sliders should be in contact with the central plate; it appears to us that the rapid motion of the slider must necessarily cause it to rebound from the plate, and leave an open space for the escape of the steam; we also apprehend that the surfaces of each slider would in a short time become so irregularly worn, that it would not fit its seat on the surface of the groove, for the top and bottom of the slider is constantly in contact with the surface of the groove during the whole of its motion, whilst the sides (speaking relatively, for there can be neither tops nor sides of a circle) are merely in contact at the time the slider is moving through a space equal to the depth of the groove. This will produce a greater wear on one part of the slider than another, and of course, in time, cause the joint to allow an escape of steam.

Another fault in this machine is, that the mode of working the sliders by means of the semi-circular rods is a very insecure method; and from the indirect application of the power necessary to work them there is a constant danger of bending the rods, and, consequently, leaving the slider in the groove. If this were to happen, the piston in its revolution would come violently in contact with the slider, and most likely cut it in two, or otherwise injure it and the rest of the engine beyond repair.*

A patent was obtained by Mr. Joshua Routledge, of Bolton-le-Moor, in the year 1818, for a Rotative Engine, of which the accompanying drawing is a section, and may be thus explained.

Suppose the steam-stop C, and the lever H *b*, to be properly packed in the situation represented by the drawing, so that the steam cannot escape past either one or the other, it will be evident that if the steam is admitted through the pipe G into the space M, the lever H *b* will be propelled forward towards C through the space Q, until the sloping part H comes in contact with the lower point of the steam stop C, which will then turn upon a steam-tight joint or centre O,

* The author of Stuart's History of the Steam Engine states—" that the general arrangement of the parts and manner of action of this engine resembles Mr. Mead's." This apology for omitting the ingenious apparatus of Mr. Mead is singular enough, since no two machines we have described can differ much more than these.



and rise up into the box or chamber D until the lever H *b* has passed by. The pressure of the steam then compels the stop C to follow the lever down the inclined plane *b*, until it comes into its former resting place, where it remains stationary upon the cylindrical part of the lever, as seen in the drawing, until again raised by the sloping part H as before. During the time that the point H *b* is passing the steam-stop C, the steam that had last carried the lever round makes its escape through the pipe B, either into the open air or into a condenser, and new steam is again instantly admitted, and so on continually. When the engine is thus constructed with only one arm or lever, there is about one-tenth of the circle or revolution where the steam has no power; the motion of the engine is then kept up by the velocity already given to the fly-wheel; but when two arms or levers are used, as in large engines, then the steam is made to act with equal force through the whole of the revolution.

A patent was obtained in the year 1818 for a Rotative Engine, by Mr. John Malam, of Westminster, which in its general principle resembles those of Messrs. Cartwright, Chapman, and Routledge: the details, however, somewhat differ therefrom. The main point of difference is, that Mr. Malam proposes to cause his external cylinder to revolve and leave the interior one at rest. This he proposes to effect by using a "leaden piston," which by its weight will always remain at or near the lowest part of the circle, whilst the steam acts upon valves or flaps which, after they pass the piston, open out and receive the action of the steam. There are three of such valves, which are exactly the same as those used in the engines of the persons just

mentioned, and operate in the same way. The piston consists of a heavy block of lead, fitted exactly by packing or otherwise to the cylinder; and the whole apparatus differs so little in other respects from those, that it is apprehended no further description will be necessary. The motive of the patentee in causing the external cylinder to revolve was evidently to avoid the inequality of wear which may arise from fixing the external cylinder, and making the internal parts to revolve; for, in the latter method, the axis and machinery attached to it have a tendency to wear downwards by gravitation, and get out of truth; this would in time cause the cylinder to assume an oval form, and thereby render it difficult to be kept tight by packing, and this (it should be observed by the way) has been considered as one objection among the many urged against rotative engines, though, perhaps, if every other could be overcome, this, on account of the length of time which must elapse before it could occasion a serious inconvenience, would not operate to prevent the successful application of such an engine.

But it must appear to all that the patentee's plan of obviating this evil is but a clumsy and ill-contrived one. The valves out of the question (the faults of which have been already explained) we cannot for a moment think that the weight or piston could afford an abutment of sufficient firmness and steadiness to produce any regular and equable motion; indeed, we doubt whether any weight placed as this was, could remain stationary whilst passing over the inequalities of such a cylinder, and enduring the varied force of the steam upon the changing of the valves. There can be little doubt but that it would vibrate to and fro as each valve opened and shut, and thereby destroy as much power by reciprocation as any beam engine ever known.

The same specification likewise contains a description of another rotative engine, in which the abutment consists of mercury, water, or fusible metal, such as lead and bismuth. In this engine there are three drums, the exterior one forms a casing or jacket to the second, and is kept heated by steam or hot air. These two outer drums are stationary, whilst the inner one revolves upon its axis, one end of which is tubular for the admission of the steam. There are attached to the moving cylinder certain curved partitions, which form chambers something like the buckets of a water wheel. The steam being introduced through the hollow axle, after filling the inner cylinder, flows into one of the compartments formed by the curved partition, and pressing upon the fluid, causes the drum to rise on that side and revolve upon its axle; this suffers the steam to enter the compartment underneath the first, (in a manner not clearly described) and force it out of the fluid. The first compartment is by this time above the level of the fluid, and the steam at liberty to escape into the channel above, which communicates with a condenser or the open air. The chambers are thus filled with steam, and raised in succession above the surface of the fluid, and produce a constant rotation of the axis.

This latter scheme differs little from the Steam Wheel of Sir W.

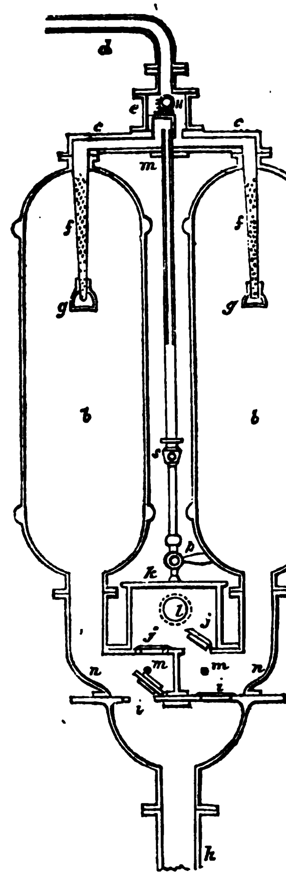
Congreve, which is simply an overshot wheel completely immersed in some liquid in which it is made to revolve by the introduction of steam underneath the inverted buckets, which by displacing the water with which they are filled, renders one side of the wheel buoyant, and causes it to ascend. By this means the buckets are successively brought above the induction pipe and filled with steam, which continues the buoyancy of the ascending side, and keeps up a constant revolution of the axis. The steam in the buckets is discharged into the air as soon as they have reached the surface of the fluid, the latter then entering them and occupying the place of the steam.

Neither of these schemes are sufficiently meritorious to demand much consideration, and only deserve notice because they have engaged the attention of highly-talented individuals. (Among these we do not mean to include Sir Wm. Congreve; for whatever may be his qualifications in other respects, he has displayed but little talent in his attempts to improve the steam engine, and even in this scheme must yield the priority of idea to Mr. Malam.) Mr. Bryan Donkin and Mr. Malam have both tried the same plan, and found that the effect bore a very small proportion to the steam expended. This was mainly attributed, in the water engine, to the large quantity of exposed liquid which is to be maintained at a temperature equal to that of the steam, and to the difficulty of getting the steam into the buckets without allowing a considerable portion of it to escape through the water without at all aiding the revolution of the wheel. An insuperable difficulty also was encountered regarding the temperature of the water, for if the water were below the boiling point, a great portion of the steam was condensed, and if at or above that temperature, the water was speedily dissipated in vapour, and required to be replenished by more water, which, if not sufficiently hot, again produced condensation, but if it were used boiling-hot, a separate boiler was necessary to supply the reservoir.

Any one of these difficulties, however, we apprehend would be sufficient to prevent success, and this may account for the failure of the mercury engine of Mr. Malam, in which it appears that the great evil would be the steam wasted, by escaping past the sides of the compartments; for without the nicest regulation of the supply of the steam, not one half of it would take its place in the bucket, owing to the facility with which it might displace the mercury and rush through it to the surface, and so to the eduction pipe. We are not able to speak as to the oxidization which would take place on the mercury when exposed to constant heat, but we apprehend this would be very considerable, and of course add to the defects of the plan.

We described in an earlier part of this work a very simple modification of Savery's plan of raising water in the engine of Mr. Nuncarrow; and from the great simplicity of another apparatus, on the like principle, we are induced to give an account of it. We allude to the machine of Mr. Pontifex, of Shoe Lane, London, whose improvement consists, it will be seen, in rendering the machine a self-acting one; but besides this, the skilful arrangement of the parts,

and the precision and certainty of its movements, makes it an object worthy of attention.



"*b b* are two steam cylinders connected by cross tubes at *c c*, in each of which a vacuum is alternately formed by the condensation of elastic vapour, connected from the boiler by the bent tube *d*, and admitted to the steam cylinders by means of the sliding valve, *e*. *f f* two tubes perforated with small holes for the admission of steam and injection water, the latter of which is distributed by falling on the strap, *g*. *h* the suction pipe, proceeding to the bottom of the well, which in no case ought to exceed from twenty-eight to thirty feet in depth; so that a vacuum being formed in the copper vessels, *b b*, the water will be raised by the pressure of the atmosphere, and passing up the tube, *h*, will take the place of the elastic vapour. *i i* two valves placed at the upper end of the suction pipe, *h*, which allow of

the upper passage of the water from the well, but prevent its return. *j j* two similar valves, opening into the air vessel, *k*, to which is attached the nozzle, *l*, serving to convey the water from the copper vessels to any required point. *m* the injection tube, furnished with a valve, and intended to convey water from the box, *n*, to the taper tubes, *f f*. *p* stop cock to regulate the supply of condensing water. There is a tube passing from the bottom of the cistern, *n*, to the injection tube, *m*, and furnished with a stop-cock at *s*. To put this engine in action the steam must be first raised to the boiling point, and the valve or cock opened, which admits it to pass from the boiler to the pipe *d*. One of the buckets must now be made to descend, which will open the sliding valve, *e*, and admit the steam into the cylinder, *b* 1. The atmospheric air, which will thus be expelled from the cylinder, is allowed to pass through the valve, *j*, and nozzle *l*. The other bucket must then be depressed, and by its action upon the sliding valve it will open a communication for the injection water through the pipe, *q q*, which passing down the perforated tube, *f*, will immediately condense the steam, and form a vacuum in the vessel. The whole pressure of the atmosphere being now removed from the suction pipe, *h*, the water will rush up to restore equilibrium, and the vessel, *b*, being filled will furnish a supply at the bent tube, *l*.

"Having examined the action on one half of the apparatus, we may suppose the same effect to be produced on the opposite side. The steam will, in the first instance, be admitted by the pipe, *c*, and a communication afterwards opened by means of the sliding valve with the condensing water, which by reducing the steam to its original bulk, will form a vacuum, and the water will again ascend as in the first vessel. The stop-cock, *y*, must now be opened, and the bucket, *x*, (first described) made to descend, which will remove the sliding valve, *e*, to its original position, and admit the steam to the upper part of the first vessel, which will depress the water and cause it to flow through the valve, *j*, and nozzle, *l*, while at the same time the water will pass through the tube, *u u*, in which the valve, *w*, is inserted beneath the inverted vessel, *v*. The water will continue to enter the bucket, *x*, till its increasing weight causes it to preponderate, and turn the sliding valve, *e*, in the opposite direction. Should there not be sufficient supply of water in the cistern, *r r*, for the purpose of condensing the steam in the larger vessels, the stop-cock, *p*, must be opened, and additional supply of water will then be furnished from the chambers, *n n*, by the tube, *m*; and in the event of the bucket not being depressed at the instant that the water is expelled from the chamber, *n*, of the vessel, *b*, the steam will pass through the tube, *u u*, and act between the under side of the fixed inverted vessel, *v*, and the surface of the water in the moveable bucket, *x*, the descent of the bucket being accelerated by the repellent force of the steam, so that, by the alternate action of the buckets, *x x*, the motion of the engine is rendered continuous.

"It appears that each steam vessel in the engine employed at the City Gas Works, contains about 36 gallons of water, which is

raised about 28 feet three times every two minutes; one bushel of coals, or two of coke, serving the boiler about two hours and three-quarters."*

In 1821 a patent was obtained by Mr. Job Rider, of Belfast, in Ireland, for a rotative engine which has been the subject of great encomium in several periodicals of the day, some of which have not hesitated to declare, that in it was to be found the solution of the grand problem hitherto sought after in vain. But although we have been favoured with some very diffuse remarks by these works, all of them have omitted to notice the fact of its being nearly a fac-simile of a machine patented by Messrs. Bramah and Dickenson thirty-one years previous to this date. We do not mean to declare that Mr. Rider is not the inventor of this machine, because although a minute description and engraving of it is given in one of the early volumes of the Repertory of the Arts, yet we well know that this work is too scarce to be found in the hands of every inventive mechanic: besides which, it is highly improbable that Mr. Rider would have incurred the expense of a patent or patents for a machine which was notoriously the subject of a previous one. It is, however, to be regretted that Mr. R. was not better informed on the subject, because the two plans resemble each other so closely, that one might almost fancy they had been drawn from the same model. We refer our readers, for a full explanation of the principle, to page 68 of this work, and have merely to add, that a respectable manufactory in Scotland expended a very considerable sum in constructing and applying one of these engines during the year 1825, but have abandoned it from the impossibility of keeping it even tolerably steam-tight.

Mr. Thomas Masterman's rotatory engine, patented 1821, comes next under our notice.

Fig. 1 represents a vertical and central section of the troke (being that part of the engine which revolves). Fig. 2 is a transverse section of it, and of the two masks after mentioned. The troke is composed of the axis, of the nucleus (being the central parts, and through which the axis passes), of the annulus (being a hollow ring, in which are placed valves), and of the radii (being the steam passages between the nucleus and the annulus). The surface of the face is a perfect plane. The axis passes though the hole (1) at right angles with the plane of the face. Six holes (2) of similar figure and dimensions with each other, are sunk in the face, at equal distances, in a direction parallel to the axis, for three or four inches; then curving into a direction at right angles with the axis, they open in the periphery of the nucleus.

The annulus (A) consists of six equal segments. At each of their joints is fixed a valve, which, by being ground on its seat, is rendered steam-tight when closed.

The radii (1, 2, 3, 4, 5, 6) are connected with the nucleus and annulus, so as to form steam-tight communications between each hole in the face and the inside of the annulus. Fig. 3 is a plan of the inner mask; being a circular plate of metal, of equal diameter with

* Partington's History of the Steam Engine.

Fig.1.

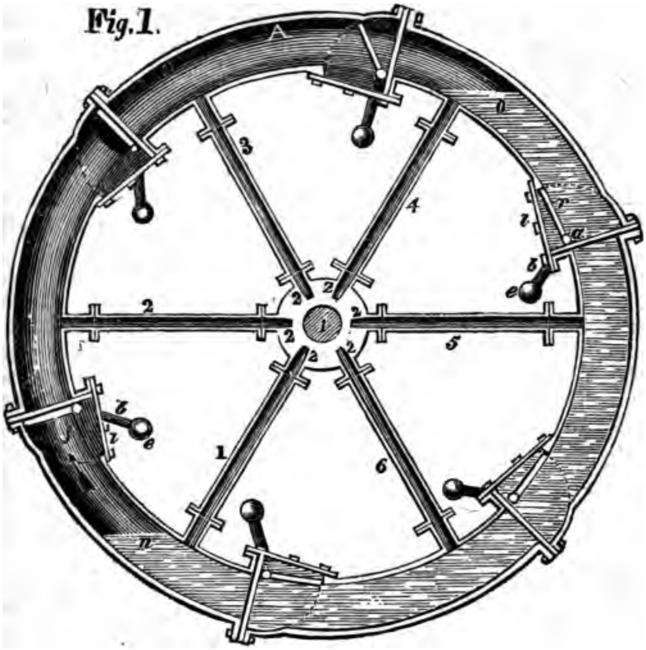


Fig2.

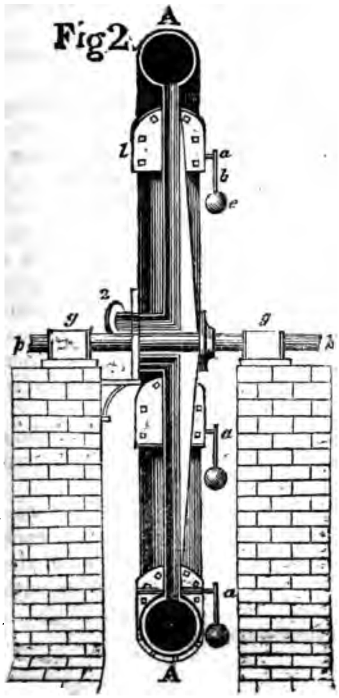
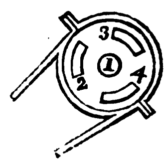


Fig. 3.



the face, about two inches thick, and having each side perfect planes parallel to each other.

There are four holes (1, 2, 3, 4) through it: 1 is of sufficient size to admit the axis; 2, 3, 4, are each one-sixth of the space that would be included by completing the two concentric circles, segments of which form the sides of those holes; and those circles are described with the same radii as the segments of those which bound the holes in the face. Thus, each of these holes would extend over one of the holes in the face, and one of the adjoining spaces: the space between 2 and 3 is of such dimensions as just to cover completely one of the holes in the face. 4 is situated so as to leave equal spaces between it and 2 and 3.

The periphery of this mask is clasped by an iron hoop, from which projects a lever, extending nearly to the annulus, and having a small inclined bar placed across its end. The two projections from fig. 4 represent the beginning of the lever.

The outer mask is a circular piece of metal of the same diameter, and about the same thickness as the inner mask.

The axis passes through both masks; the inner mask is placed next the face, the other next the inner mask, and both are kept closely pressed towards the face (by means of screws acting on the back of the outer mask) so as to be steam-tight with each other and with the face: a trifling pressure suffices to make them so, the opposed surfaces having been ground on each other. The outer mask is placed in such a position with respect to fig. 1, as that the pipe 2 may be horizontal, and point towards radius, fig. 2, and it always remains stationary. The inner mask is placed in such a position with respect to the outer mask, as that the holes 2, 3, 4, in the former may communicate with pipes corresponding in the latter, and thus form a communication between the pipes communicating with the boiler and the air. Thus the holes in the inner mask are for the same relative purpose as the pipes in the outer mask.

The transverse sections of both masks, placed in their relative positions, are represented in fig. 2.

The corresponding letters in fig. 1 and 2 refer to the corresponding parts in figure: *p p* is the axis, *g g* are its bearings.

As the valves, and the gear for regulating them, are precisely the same in each segment of the annulus, only two of them (one showing their position closed, the other open) are lettered for reference.

Each valve *(f)* is similar to the other, and opens in the same direction; its gudgeons, moving freely in sockets, fixed to the sides of the annulus nearest the axis.

Their working-gear is as follows: *a* is a small hollow protuberance or bonnet screwed on the annular, and communicating with the inside of it; on one of its inner sides is a socket, on the opposite a stuffing-box; one end of a spindle works in the socket, the other passes through the stuffing-box to the outside of the bonnet; to this end is attached the lever *b*, and to the centre is attached the lever *c*; both levers being at right angles with the spindle, and in the

opposite direction to each other. To the extremity of *c* is attached (by a moveable joint) the rod *d*, and to the extremity *b* is fixed the weight *e*, being more than sufficient to counterpoise *f*, which is connected with it by means of a moveable joint at the other end of *d*, and attached to the centre of *f*. The levers are so placed as to cause *f* to be half open when they point to the axis. Thus it is evident that, during the revolutions of the troke, two of the valves (*f*) on its ascending side (denoted by the arrow) will, by the mere preponderance of *e*, be shut, and the whole of the others will be open, as represented in fig. 1.

For more easily comprehending the action of these valves, let it be considered that their movements are regulated by the mere gravity of *e*.

The machinery to which motion is to be imparted is attached to that end of the axis next fig. 1.

The steam is generated and condensed in the usual manner.

The principle on which the engine acts, is by a liquid body (water or mercury for instance) placed in the annulus, being pressed on one side of the troke by the steam, until that side gain such a preponderance over the other as to overcome the resistance of the machinery attached to the axis, and by being then sustained there, so as to maintain the preponderance during the revolution of the troke.

The engine represented by the engraving is one in which water is the liquid made use of in the annulus. The manner in which it is worked is as follows:—

The annulus is nearly half filled with water, which need never be withdrawn. The troke is placed so as to have two of its radii in a vertical position. The steam-cock is turned; consequently the steam rushes through the pipe and hole (2) in the outer and inner masks, and through the lowest hole in the face into the lowest radius; and, after imparting to the surface of the water in that radius its own temperature, it presses such water downwards, and flows into the annulus, condensing in the water therein, until it has imparted to it, also, its own temperature, which will be rapidly accomplished. On the temperatures becoming alike, the steam will rise through the water on both sides of the troke, and, meeting with a closed valve on one side, will press the water which is beneath it downwards, and consequently cause the water on the other side to rise proportionably, until the preponderance thus given to that side be sufficient to overcome the resistance of the machinery attached to the axis, immediately whereupon the troke will begin to revolve. The load, or resistance of the machinery, remaining the same, and the supply of steam being equable, the water will remain nearly stationary during the revolutions of the troke: its surfaces are denoted by the lines at *n* and *o*.

As the troke revolves, each of the holes in the face communicates in succession with 2 in the inner mask.

It should be borne in mind, that, as has before been observed, the position of the inner mask is never so far changed as to prevent

2 and 3 therein communicating with the corresponding pipes in the outer mask, when the engine is at work.

By the construction, one entire hole in the face, or parts of two, equal to one, is, or are always in communication with 2 in the inner and outer masks; so that there is always an equable flow of steam into the annulus, preventing the depressed surface of the water rising with the ascending closed valve.

The holes in the face, as they pass in succession from 2 to 3 in the inner mask, are entirely closed by the space between them; and immediately on communicating with 3, the steam confined between the two closed valves rushes from the annulus, through 3, into the air, or into the condenser, if one be used. And until the same hole in the face has passed 3, a communication with the air, or the condenser, remains for the discharge of the steam.

The pressure of the steam being thus removed from each valve, (*f*) as it arrives at this point, it will, by the gravity of *e*, open as it begins to descend, (see the valve partly open in fig. 1) and thus allow the column of water to remain on that side of the troke.

The water will fill the radii as their ends descend beneath the elevated surface, *o*, and will remain there until the steam presses it out at about *n*, but cannot escape, if before it enters them the hole in the face has pressed the hole 3; otherwise, however, the water would escape through that hole into the air, or condenser.

A uniform rotatory motion is thus produced and maintained as long as the steam flows equably into the annulus, acting with a force proportionable to the preponderance of the water on one side of the troke over the other. This force is easily estimated, being equal to the weight of a perpendicular column of water, having the difference of the two levels for its altitude, and the area of a transverse section of the annulus for its base, pressing against the closed valve.

This description of Mr. Masterman's engine is copied from a pamphlet published by Messrs. Underwood in 1822, which gives a very clear description of the whole machine, together with a detail of the comparative advantages the writer imagined this machine to possess over the reciprocating one. Although this work, written merely for the purpose of elucidation, and proceeding from the pen of a mechanic who may not possess much talent as a writer, can hardly be a fair subject of criticism, yet, as it will serve our purpose best, in treating on this machine, to follow the author through some of his remarks, we will step out of our usual course in the present instance.

The difficulties which are stated to have been obviated or lessened by the invention of this engine are, "1st, The skill and nicety of workmanship required in construction and erection; 2nd, The cost of construction and erection; 3rd, The space they occupy; 4th, The expense of working and keeping them in repair; 5th, The power lost by friction, by alternate movement, and by the oblique direction in which the power is exerted through the medium of the crank rod; 6th, The great pressure of steam required to work with any economy without a condenser; and 7th, The trouble of putting them in motion when they stop with the crank in a vertical direction, and the care required to prevent the fly-wheel taking a reversed motion."

Before going into Mr. Masterman's remarks as to how far these faults are obviated, it may be worth while, in the first place, to see whether all of them exist. On this it may be said, that the first, second, third, and fourth, are evils which have justly occupied the consideration of nearly all mechanics since the general adoption of the steam-engine, and are in reality evils of such a nature as to be evident to every one.

But in the fifth enumerated evil the author has fallen into a very great though a very common error, in conceiving that power is lost by the oblique position in which the crank receives the force of the steam. We have had occasion more than once to lament that the erroneous idea formed on this subject, has led many able mechanics into great expense. Perhaps it is not incorrect to say, that one half of the rotative engines which have been attempted, would never have been undertaken, had the different patentees been fully aware that no saving is effected by increasing the length of the lever upon which the steam exerts its force. These engines have generally been encumbered with an interior cylinder, or drum of such a diameter, as to cause a considerable friction, the purpose of such drum being to prevent the steam from acting near the centre of motion, where it was conceived it would be ineffective. Had this supposition been true, Mr. Masterman's engine would have had ten times the effect of any other: for the diameter of the experimental engine being 30 feet the lever would generally be ten times more than the average length of a crank of a reciprocating engine of the same power.

The sixth disadvantage stated, as attendant on a reciprocating engine is the great pressure of steam necessary to work it without a condenser. This is undoubtedly a difficulty which is of no small moment, and Mr. Masterman's engine (if it had succeeded in other respects,) would have bid fair to have completely obviated it. The force of steam necessary to give motion to an annulus of a large diameter being as much less than that excited on a crank, as the length of the crank is less than the semi-diameter of the annulus. Hence a pressure of 7 or 8 pounds per square inch would have produced the same effect in this engine as 70 or 80 pounds per square inch would have produced when exerted on a crank of 18 inches in length.

The eighth disadvantage stated—" is the trouble of putting a steam engine in motion when it stops with the crank in a vertical position; and the care necessary to prevent the fly-wheel taking a reversed motion. There is no doubt that it is a very great inconvenience, when the engine stops with the crank in a vertical position, particularly in large engines; and we have frequently seen it necessary in such cases to call in the aid of several workmen, and lose a considerable portion of time before the engine could be put in motion, and that not unfrequently when considerable mischief was occasioned by such a delay. But there are very few cases, in which it is not expedient and absolutely necessary to have the power of reversing the motion of the engine. Mr. Masterman, therefore, as-

sumes that to be an advantage which in reality is an unsuperable objection to the general adoption of any machine not possessing the power of revolving either forwards or backwards. In steam boats particularly (where Mr. Masterman is sanguine enough to imagine his mercury engine could be applied with advantage) the capability of easily reversing the motion is a point of first consideration, and without such power no one could guarantee their performing a short voyage with safety.

Having shewn that many of the objections here stated do not exist, we shall proceed to inquire, how far those which do, are obviated by this machine. And we shall first state that we have had frequent opportunity of inspecting the engine which was erected by Mr. Masterman at Fawdon colliery, near Newcastle; the *troke* of which was 28 feet in diameter, and which *ought to have been*, according to his calculation, of 12 or 13 horses power. We are enabled therefore to speak from our own observation; in addition to which, we have been favoured with particular information on the subject, by the managing engineer of Fawdon colliery.

It appears that the "skill and nicety of workmanship" is by no means lessened in this machine, but on the contrary, the cost of it must greatly exceed that of the reciprocating engine. It is stated that "the *only* parts requiring any nicety are the valves, valve-seats, face, and masks which must work steam tight." Were these all, it will readily be conceived that the care required in fitting them up, must greatly exceed that of a reciprocating engine; there being no less than 28 surfaces of brass and metal to be made perfectly smooth and steam tight by the usual processes of filing, turning, and grinding; whereas in the common engine there are but two, requiring such nicety. It follows, therefore, that the cost as well as the skill, required in the construction, must exceed that of the latter.

In remarking on the comparative friction of the two kinds of engines, it is observed, that "as the valves are regulated by the gravity of the weight, there is no friction in the pins." This is an absurdity which shews a want of information of the writer, since it is evident that these *weights*, by the falling of which the valves are worked, must be raised by the power of the machine, to the elevation from which they fall: as much force, therefore, must be exerted to elevate them, as would have been necessary to have moved the valves by the more direct action of the machine. The blunder reminds us of a similar one, which we observed in Brown's Gas Vacuum Engine, where a short beam was made tubular, and charged with mercury, from the idea that this would aid its movement.

But these defects are of little importance, and scarcely deserve the notice we have given them. We shall now shew what appears to have been the cause of failure. This seems chiefly to have been the great condensation, arising from the exposure of the steam in the annulus. The steam occupying one half of the circle becomes dispersed, as it were, in a long bended pipe, which is subjected to the disadvantage of passing through the air by which the condensation must be increased. Another cause of condensation is the dif-

ference in temperature, between the depressed and the elevated surfaces of the water." The lower surface being continually in contact with the steam, is nearly of the same heat, whilst the upper surface is considerably colder. Now the different segments of the troke, successively lose a portion of their caloric, as they *pass over* the cooler portion of the liquid; and in this cooled state become the recipients of the steam; and although there is a tendency in the machine to bring all parts of the water to an equal temperature, it was found preferable to prevent such a consequence, by a supply of cold water, as the elevated surface when so heated expanded into steam, and escaped through the discharging pipe.

Another and secondary cause of waste takes place, when there is the least variation in the resistance of the load; when that is uniform, the steam exerts merely the force necessary to overcome it; but upon the resistance being increased, the steam then forcing upon the yielding surface of the water, without immediately producing the required speed, drives a considerable quantity of it over the upper part of the annulus, into the empty side of the wheel; and by occupying its place, rises by its inferior gravity upwards through the water, and escapes through the discharging pipe without producing any effect. When this takes place, it is some time before the water returns to its proper situation, or becomes a sufficiently steady abutment to produce the required powers.

The consequence of these defects were extremely apparent in the engine alluded to; the waste of caloric being such that few persons could endure the heat of the engine-house when the engine was working. The waste by condensation was so great, that it required a boiler of sufficient capacity to have worked a reciprocating engine of 36 horses power, merely to drive a small circular saw, which could have been easily driven by an engine of 2 or 3 horses power. The varied resistance produced by sawing wood, rendered the last-named defect very apparent; and, indeed, considering the degree in which its effect was weakened by the *irregularity* of its load, perhaps a saw was the most ill-judged application of its force.

We have been thus particular in our investigation of this ingenious machine, because several scientific friends were disappointed by its failure, and because both Partington and Stuart have anticipated, that "if ever rotatory engines should be brought into successful competition with the common steam engine, it appeared probable that they might be constructed on this principle." We perfectly agree with the latter writer, however, in this opinion, that much credit is due to Mr. Masterman for his very clear and interesting account of his machine, and the candid appeal which he makes to experiment. We trust in examining the pages of his little pamphlet that we have been divested of every prejudice, and that our apparently severe examination will be attributed to the proper motive. It is sincerely to be wished that more would follow his example, and fairly submit their inventions to the public, divested, like his, of all mystery and quackery; the advantages which would arise from this liberal proceeding would be incalculable.

CHAPTER VII.

PERKINS'S ENGINE.—BRUNEL'S IMPROVEMENTS.—VAUGHAN'S ENGINE.—ALBAN'S ENGINE AND GENERATOR.—BROWN'S GAS ENGINE.—BRUNEL'S GAS ENGINE.—METALLIC PISTONS.—BEALE'S ROTATIVE ENGINE.—FOREMAN'S ROTATORY ENGINE.—EVE'S ROTATORY ENGINE.—MARQUIS DE CAMBIS' ROTATORY ENGINE.—GALLOWAY'S ROTATORY ENGINE.—CONCLUSION.

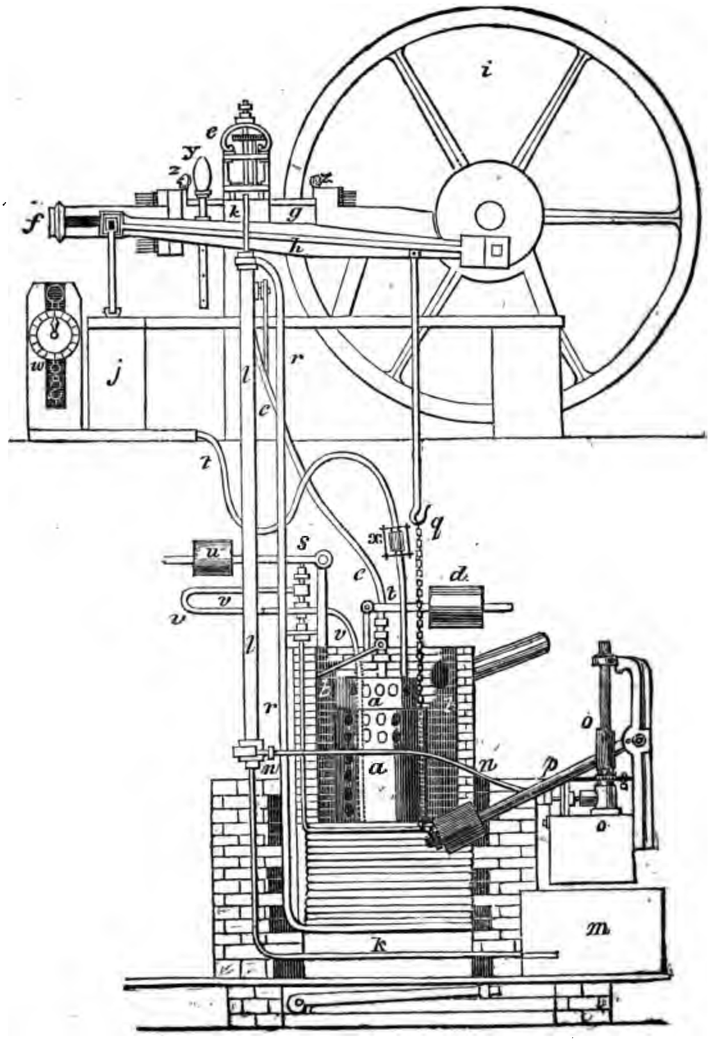
It has been shown in an early part of the work, that a high pressure engine consumes less fuel than a condensing engine of the same power, and that the force of the steam per square inch increases in a much greater ratio than the temperature communicated to the water. This fact fully establishes the superior economy of a high pressure engine, and it also proves, that the more the pressure is increased, still less fuel *proportionably* will be required. Though this curious phenomenon is universally known, yet few attempts had been made in England to use steam of a pressure exceeding 50, or at most 100 pounds on the square inch, until the recent experiments of Mr. Perkins. This delay among our engineers to adopt what would seem to promise such great advantages, must be attributed to a caution which has been well grounded. The great danger of explosion must have been quite sufficient to have deterred them from the trial; and until that could be effectually guarded against, it would have been madness to increase the pressure of steam beyond its present limits. It is, indeed, no uncommon circumstance to find boilers in America loaded to double and sometimes treble the pressure of the greatest force we have now named; but still, with boilers of the usual construction, the danger must be very great, and the liability to accident such as to more than counterbalance all the advantages that can be obtained.

Mr. Perkins, however, conceived that all this saving could be effected, and that danger could be removed, by reducing the size of the boiler. We shall give Mr. Perkins's own remarks on the subject:—

"It is a well known fact that water does not boil under atmospheric pressure until it has been heated to 212°, after which all the heat that can be applied cannot increase the temperature of the steam or water. Now, add an artificial atmosphere by loading the escape valve (the surface of which is equal to a square inch) with 14 lbs. and it will receive 250 of heat with a very little addition of fuel, and the pressure on the square inch will be doubled, or 28 lbs.; the mechanical action will not be double, yet it will be increased much more than the consumption of fuel. Let the valve be loaded with two additional atmospheres or 42 lbs. and the temperature will be raised to 280°, and will again produce double pressure, or 56 lbs. in the inch, and so on. If the generator be made strong enough, as I have no doubt it may be, to withstand 60,000 lbs. load on the escape valve, the water

would not boil, although it would exert an expansive force equal to 56,000 lbs. on the inch, and be at about 1170° of heat, or cherry red. Water thus heated would, if it were allowed, expand itself into atmospheric steam, without receiving any additional heat from what surrounded it. It is not, however, necessary to heat the water to more than 500° to have it flash into steam, if the generator be properly constructed."

a a is the generator, kept constantly filled with water up to the valve; *b b* is the furnace surrounding the generator, by which the water it contains is intensely heated, but is prevented from escaping,



notwithstanding its great expansive force, by the enormous pressure upon the valve by the variable weight *d*; or until the pump *o* has forced a given quantity of water into the lower part of the generator, which raises the valve, and causes a like quantity of the heated water to escape into the pipe *c c*, where flashing instantaneously into steam, it rushes into the cylinder *g* and drives the piston *f* to the farthest end of it; this action causes a communication to be opened into the pipe *k* into which the steam passes; the pipe *k k* passes through the condenser *l l*, delivering out its heat to the cold water contained therein; from thence after descending it takes an horizontal course and enters the reservoir *m*, from whence it is re-pumped for use by the apparatus *o o*.

The arm *h* is attached at one end to the piston *f*, and is consequently moved by it in an horizontal line the length of the cylinder *g*, and the other end of the arm being connected with the fly wheel *i*, causes it to revolve; the fly thus put into action gives motion to the rotatory valve *e*, which opens and shuts alternately a communication on both sides of the piston. An iron rod and chain *q* being fixed to the arm *h*, and at the other end to the loaded lever *p*, the pump *o* is worked by the action of the arm, causing at every revolution of the fly a fresh quantity of water to be forced into the bottom of the generator, which again raises its loaded valve, and allows the escape of an equal quantity of water into the pipe *c c*, where flashing into steam, and rushing into the cylinder, it operates upon the piston again and keeps up the alternating and rotatory motion of the several parts before mentioned.

The condenser *l l*, is a tube of copper about 4 inches in diameter and 20 feet long, and is supplied constantly with cold water from the pump, through the pipe *n n*. This enters the condenser at the lower end, and is discharged at the upper end into the descending tube *r r*, which proceeding to the lower part of the apparatus, ascends in a spiral winding of many coils round the bottom of the furnace up to the valve *s*, loaded by a variable weight *u*, equal to 700 lbs. upon the square inch (or about 50 atmospheres); from the valve *s*, the tube descends as at *v v v*, and proceeds to nearly the bottom of the generator, as shewn by the dotted lines. In order to insure safety to the apparatus, a tube *t t*, is fixed to the generator and proceeds to the dial *r r*, showing the degree of pressure or the number of atmospheres at which the machine works. Near to the middle of this tube is fixed a safety valve of copper, *x*, which is torn up when the pressure greatly exceeds the intended force. The atmospheric air contained in the spaces on each side of the piston escapes by tubes at *z z*, furnished with stop cocks.*

Such is Mr. Perkins's engine. The experiment, as far as it regards the generation of steam of this enormous pressure, has been quite decisive, but the *economy* of engines on this principle has not been so fully established. It appears that Mr. P's principal difficulty has been, not the generation of the steam, but its application

* Register of Arts and Sciences, vol. i. p. 369.

to the machinery. This difficulty has been owing to the high temperature, which the cylinder and working parts acquire when in operation, which produces several inconveniences, the main one of which is, that it is absolutely impossible to lubricate the sides of the cylinder or valves, with oil, tallow, or any such material, although it is well known, that metallic packing cannot be maintained, even in a condensing engine, tolerably steam tight without some such application; and if such a difficulty occur in a low pressure engine, how much greater must that difficulty be in an engine, working at the great force of steam at which this is worked, especially when we consider the very subtile nature of such steam, and the much greater proportion that the openings (through which the escape is) bears to the surface of a piston on this principle, than similar openings in a metallic packing, bear to the surface of a piston of a condensing engine. The reason why it is impracticable to apply oil, is, that the great temperature of the cylinder instantly carbonizes it, or causes it to pass off in vapour, and in that form escapes to the atmosphere. Another inconvenience is, that the materials of which the piston and valves are composed, become by wear and friction (both of which are increased by the cause just named) speedily destroyed.

In order to obviate some of these evils, Mr. Perkins has just taken out another patent, in which it is stated that he has discovered a method of forming a metallic piston, of a peculiar alloy, requiring neither oil, tallow, nor any lubricating material whatever, to reduce the friction; on the contrary, by the working of the engine, the rubbing surfaces of the piston and cylinder become so highly polished, as to reduce the friction, considerably below that of the ordinary metallic packing when oiled.

There have been so many exaggerations and misrepresentations respecting this engine from first to last, that we cannot venture to give credence to any thing on the subject, without seeing this alleged improvement in actual practice, or attested by men of credit and respectability; certain it is, that Mr. Perkins's engine can never answer, without such an *alloy* as that alluded to; and it is equally certain, that if a material possessing these qualities has been discovered, its utility will not be limited to the steam engine alone, but will be equally applicable to machines of almost every modification.

Mr. Marc Izambard Brunel obtained a patent in 1823, for a very ingenious application of the steam engine, by which the connecting rods of two cylinders are made to give motion to the same crank: the following figure and description will enable our readers to understand it.*

Fig. 1 is a front elevation, and Fig. 2 a plan or bird's-eye view of the engine, divested of the various gear and appendages employed in communicating its power; in order that it may be clearly and readily understood.

* Register of Arts and Sciences, vol. iv. p. 327.

a a a is a strong triangular frame of cast iron, containing the two working cylinders, *b b;* these cylinders are inclined towards each other, so as to form an angle of 102°, that particular angle having been found by Mr. Brunel to be preferable to all others in effecting a rotatory motion to the crank, by the alternating action of the piston rods. *c c* are the piston rods; *d d* the connecting rods, attached to the revolving crank *e e,* which by its axis communicates motion to whatever machinery may be connected thereto; *f f* are metal rollers, running upon guide plates, to give support to the pistons, and thereby equalise their friction in the cylinders.

The steam is received from the boiler into the small cylinders *g g,* and, by the action of the pistons therein, the steam is alternately admitted into one of the ends of the working cylinders, *b b,* and a passage opened for its escape at the other. The action of the pistons in the small cylinders, *g g,* is effected by eccentrics, placed upon the axis of the main crank *e,* as may be seen at Fig. 2; these eccentrics give motion to the rods *h h,* which, by the intermediate levers shown, operate upon the pistons in the small cylinders.

One of these engines, applied for the purpose of draining the Tunnel now] being cut under the Thames, and, as represented by Fig. 1, is fixed on the top of a lofty massive frame work, or tower

Fig. 1.

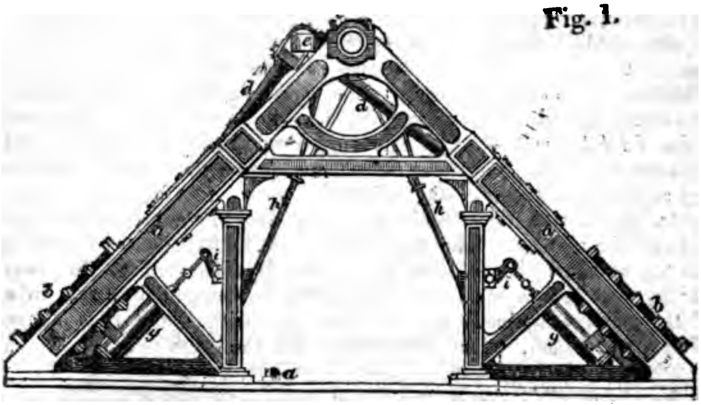
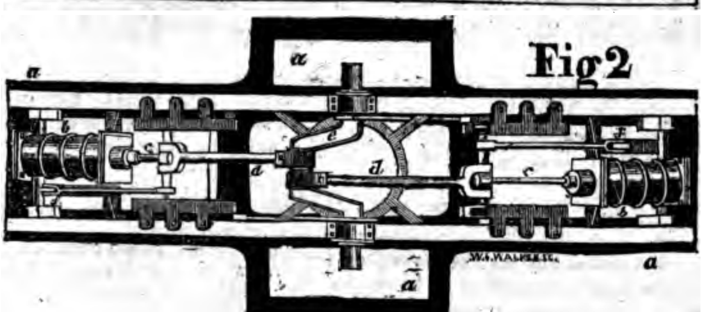


Fig2



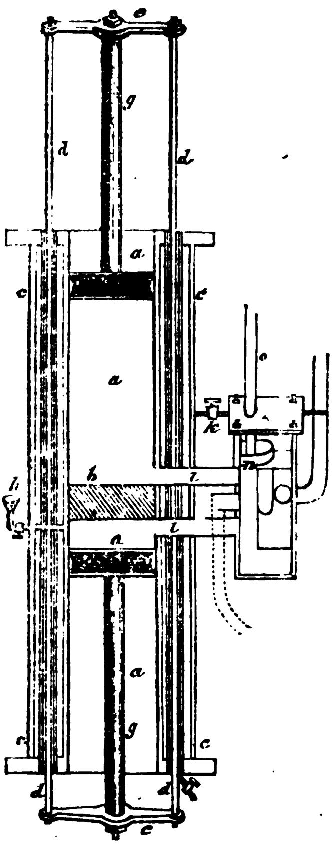
of wood, built up from the bottom, and in the centre of the great vertical shaft of the tunnel, and is further strengthened by numerous large transverse beams, the extremities of which enter the masonry at the sides of the shaft. On the axis of the crank is fixed a small fly wheel as at *k*, and on the same shaft a toothed pinion *l*, which gives motion to two toothed wheels *m n*; to these wheels are attached the crank levers which work the pumps; on the shaft of the wheel *n* a drum wheel is fixed, over which a band, *p p*, works; this band passes over another drum wheel (not brought into view); from that another band gives motion to a rigger, at a considerable height above the engine, which rigger carries also another endless band or strap, which is the immediate agent employed for drawing up the excavated earth in strong square receptacles or small waggons, upon wheels, which, when raised over the platform (as shown by the diagram) are wheeled off to their destination upon an iron rail-way.*

A patent was obtained in 1824, by Mr. George Vaughan, of Sheffield, for a very curious application of the old open topped or atmospheric steam engine, which we here give, not from any faith in the alleged advantages derivable from its use, but from the novelty of its appearance.

"Fig. 2 represents a section of the cylinder. *a a a a* is a cast-iron cylinder, open at both ends, and bored true; *b* a partition in the middle of the cylinder, *a*, which may be either cast in or bolted in afterwards; *c c c c* is a casing cast round the cylinder *a*, with a flange at the top and at the bottom, and another a little below the middle to fix the cylinder in its place, which casing is for the purpose of heating the cylinder, and keeping it hot in the usual way; two side rods, *d d d d*, work through two copper or other metal pipes fixed between the casing and the cylinder, which pipes are rivetted to the top and bottom flange of the cylinder; *e e* are two cross bars connected to the side rod at both ends, and also to the top and bottom rods of the pistons. The upper piston is represented as nearly at the top of the cylinder. The piston rod is connected to the cross bar by a socket in such bar, which bar is suspended in the links of the parallel motion. *g g* are the two pistons and rods above alluded to, which, when connected with the cross bars, *e e*, move together, producing what I call one stroke with two pistons. *h* is a cock and funnel for conveying grease through the casing and the cylinder to the bottom piston close to the partition *b*. *i* is a cock at the

* As the quantity of water that collects in the Tunnel is very inconsiderable, it is found that the working with one cylinder only, (that is, half the engine,) is sufficient to raise the whole, as well as all the excavated earth to the surface. If an increase of power should at any time be required, it may instantly be obtained by connecting the opposite piston rod to the crank. Thus the engine may be adapted with facility to whatever circumstances may require of it. The power of the engine is calculated at thirty horses, that is to say, each cylinder operates with the power of fifteen horses.

The pistons now used in this engine, are, we understand, of the expanding metallic kind, those made and patented by Mr. Barton, a preference being given to those above all others by Mr. Brunel, which is, in our opinion, no small recommendation of them.



bottom of the casing, to let out in the usual manner the condensed steam from between the casing and cylinder. *k* is the cock and pipe to convey steam from the steam pipe into the casing of the cylinder; *l l* represents two passages which are cast in a branch proceeding from the cylinder and casing, the one passage communicating above the partition *b*, and the other below, to convey steam in and out from under the top and above the bottom piston. *m* is a passage to convey steam from under the slide valve into the condenser, which is cast in the same branch in the usual way. *n* is the slide valve inclosed in the steam box, having the steam pipe *o* connected with such box. The slide or other valve may be moved in any of the known methods employed for that purpose."*—

The steam being admitted through the upper passage *l* into the upper chamber of the cylinder, its piston is thereby thrown up, and

* Register of Arts and Sciences, vol. ii. p. 67.

the vacuum being immediately formed in the usual way, the pressure of the atmosphere of course operates instantly to thrust it down again, whilst at the same moment a corresponding effect is being produced upon the piston in the lower chamber, by the steam rushing into it through the lower passage *l*, thus co-operating with the atmospheric pressure from above, in producing what the patentee calls "one stroke with two pistons." A vacuum being next formed in the lower chamber, the atmospheric pressure acts upon the lower piston, while the steam, again admitted through the upper passage *l*, assists in like manner in throwing up both pistons as before, and thus by alternately allowing the steam to rush through the two passages *l l* into the upper and lower chambers, a constant uniform motion is produced and kept up.

The advantages stated to be derived from this engine are, that by the united application of the force of steam from the boiler on one piston, and the pressure of the atmosphere on another, a greater power is obtained, than can be by the Bolton and Watt engine, where the air is excluded. The error of the patentee seems to have arisen, from his not being conscious that steam acting in a boiler, at the pressure of 4lbs. on the inch, would, in a vacuum, exert a force equal to 4lbs. + the pressure of the atmosphere, or $4 + 14\frac{3}{4} = 18\frac{3}{4}$ when therefore, we unite, as in the present instance, the pressure of the atmosphere to that of the steam, we obtain only $4 + 14\frac{3}{4} = 18\frac{3}{4}$, being the same result in both instances. This complicated machinery therefore answers no other end, than of increasing the friction, and adding to the expense.

Mr. J. C. C. Ruddatz obtained a patent in 1825, for an invention of Dr. Ernst Alban, a physician of Rostock, in the grand duchy of Mecklenburgh. This gentleman has since removed to England, for the purpose of introducing his invention, which consists, like Perkins's, of an attempt to reduce the consumption of fuel, by increasing the pressure of the steam; but Dr. Alban's apparatus is much more novel and ingenious.

The vessels wherein the steam is immediately generated, are of a very narrow compass, and made of tough metals, on which account they are very durable, although not constructed of any great thickness. They consist of tubes of small diameter, which are calculated to sustain a pressure of 4 to 6000 lbs. to the square inch, thus removing all chance or possibility of their bursting, an event which, even if it could happen, this construction would render perfectly harmless. These generating vessels have only about one foot of steam producing surface to the horse power, and in order that the generation of steam may be increased to such a degree, that the intended effect can be produced, and in order at the same time to withdraw them from the destroying influence of the fire, they are placed within a medium, consisting of an easily fusible metal, or metallic mixture, such as tin and lead, which is introduced into a tank or vessel of cast iron, and exposed therein to the action of the fire. In these latter, which Dr. Alban calls his metal vessels, he opposes a very extended surface to the action of

the fire, without infringing on space, or requiring any great quantity of the fusible metals for filling them, as may be easily seen by reference to the form of the metal vessel, *fig.* 2. By this means caloric is conducted in large portions to the medium, which being a good conductor of heat rapidly imbibes it, and forms, as it were, around the generator, a store of caloric, which it gives out so equably and rapidly, that the tubes, with but a small generating surface, collect and give out to the water which is to be converted into steam, as much caloric as if that surface had been ten times the size upon the ordinary construction. Both the metal vessels and the generator present an inconsiderable surface to the atmosphere, and in this manner the inventor has sought to prevent any condensation in the generator of the steam already generated, as well as to prevent, generally, any disadvantage resulting from the radiation of caloric.

The water is conveyed into Dr. Alban's generator, only in the quantity required to produce a given and continuing effect. For this purpose the forcing pump, by means of which the injections are supplied, is made to regulate itself in such a manner that it either moderates or entirely suspends the injection of water, according to the state of pressure in the generator. The steam generation is thus entirely independent of the management of the fire by the stoker, and is at all times subservient to the wants of the engine to which this apparatus may be applied. All possible danger would likewise be removed by this means, even in the absence of any safety valve. When it is required to stop the engine, it is only necessary to put the forcing pump out of action, and the generation of steam ceases of necessity.

In order to prevent the metallic fusion from being overheated, in cases where a smaller supply of steam is required, or where a suspension of steam generation takes place, by the stoppage of the engine, or otherwise, the inventor has arranged a heat regulator, which regulates the intensity of the fire. This apparatus indicates the degree of temperature of the fusion, upon which solely its action depends, and the generation of steam in the generator has no influence whatever upon it; the regulator continuing to act when the generation of steam has ceased, on which account it is essentially different from any heat regulator hitherto used. Its application is indispensable to this apparatus, in order to prevent so great a heating of the generating tubes as might occasion a decomposition of the water injected therein.

The very great saving of fuel occasioned by this invention is accounted for, partly in consequence of the steam being produced at so very high a pressure, and partly by the circumstance, that the metallic medium, when in a state of fusion, is one of the best conductors of heat in nature, receiving and collecting the heat within itself very quickly, and without loss, and thereafter giving it out in a concentrated form to the generator. Owing to the constant motion kept up among the hotter and colder parts of the metallic fusion, as in the case of heated water, the more heated portion having a tendency to ascend, while the cooler part descends,

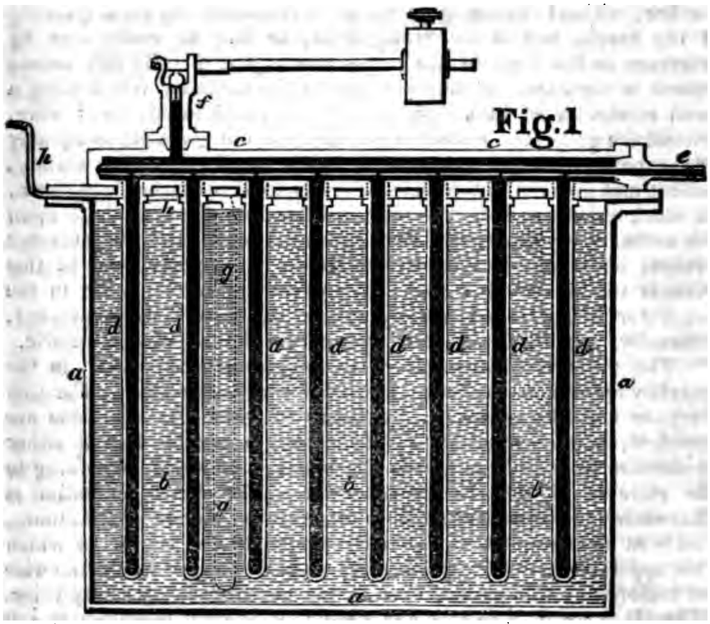


Fig. 1

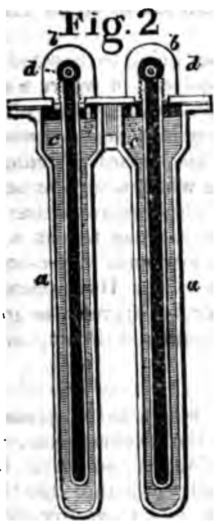


Fig. 2

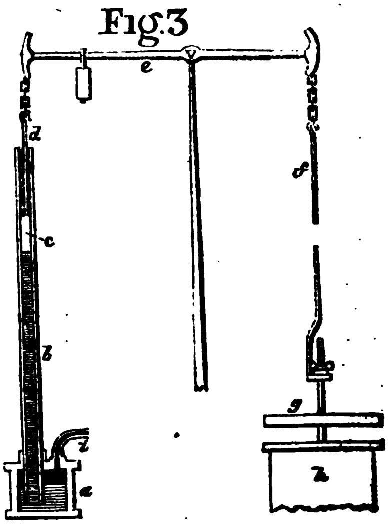


Fig. 3

the caloric is distributed very quickly and equably through the whole body. All congealment of the metallic medium is avoided, by using such an admixture of metals, as will fuse at a temperature lower than that which the steam receives within the generator. In

ordinary boilers, the heat of the fire acts upon a bad conductor of heat, water, and upon a proportionable large body thereof, the parting with its heat cannot, therefore, be free or quick, and in order to produce any powerful effects, it is necessary to oppose a very large surface of the boiler to the action of the fire.

For the reasons stated, it is, however, quite otherwise with this new apparatus for generating steam, and the surface opposed to the action of the fire is therefore considerably less, in proportion to the generation, than in ordinary boilers. The rapid generation of steam, by this method, is likewise much favoured by the circumstance, that water is injected in small quantities only, and is distributed on all the sides of the generator.

Figures 1, 2, and 3, are representations of the generating apparatus, constructed in London, under the superintendance of the inventor. It has a double metal vessel, and two generators; *fig*. 1, is a longitudinal section thereof, *a a a*, is the cast iron metal vessel. *b b b*, the metallic mixture. Supported upon the lid or cover of the metal vessel, is the strong top of the generator. *c c*, containing a cylindrical chamber of two inches diameter; *d d d d*, are the wrought iron generating tubes, suspended in the metallic fusion; they are of 1½ inch bore, and are screwed into the top *c c*, so that they may be taken out whenever they require cleaning. *e*, is the injection pipe, made of copper, through which the water is conducted into the generating tubes, over each of which a small hole is perforated. *f*, is the steam pipe, connected with the engine and the safety valve.

Fig. 2 is a transverse section of the double metal vessel; it is freely suspended in the furnace, and exposed on all its four sides and its ends, to the action of the fire, so that although it is but 4 feet long, 3½ feet high, and, including the space between each vessel, takes up only 9 inches in width, it exposes to the fire a surface of sixty square feet. *a a*, is the double metal vessel; *b b*, the two generators; *c c*, the two injection tubes, which are joined together externally, and communicate in one pipe to the forcing pump. This pump is of the usual construction, furnished with a lever and weight, which are raised by the engine, through any of the known means. If the production of steam in the generator be too great for the wants of the engine, the pressure in the steam chamber will act against the injection, and the weight will be insufficient to force down the piston of the pump, which will thus remain inactive, until the pressure is diminished, by the ceasing of production and the expenditure of the engine.

The heat regulator consists of two pipes filled with atmospheric air, one of each being inserted into each metal vessel, *fig*. 1, *g*, and surrounded by the metallic medium; to both pipes, very narrow tubes are fixed, *fig*. 1, *h*, and *fig*. 3, *i*, which are joined together externally into one tube, which opens inside the mercurial cistern, *fig*. 3, *a*; within the mercury therein contained, is immersed a vertical tube *b* with a float *c* swimming on the top of the mercury. This float is connected, by means of the rod *d*, with the lever *e*, and acts by the rod *f*, upon the damper *g*, which regulates the

draught of the fire in the ash-hole. When the air in the pipes *fig.* 1, *g g*, becomes heated by the fusion, it expands progressively as this becomes hotter, presses on the mercury in *a*, *fig* 3, and causes it to ascend in the tube *b*. By the rising of the mercury, the float *c* is made to ascend likewise, and acts by the rod *d* on the lever *e*, and thereby on the damper *g*, so that should the temperature of the fusion be greater than is required, it gradually closes the air hole *h*; the supply of air to the fire is thus prevented, and the heat is consequently diminished.*

Of all the inventions which have lately excited the public attention, perhaps none has been more the subject of discussion, than the apparatus patented in 1823, and again (for improvements) in 1825, by Mr. Samuel Brown, of London, and called a *gas vacuum engine*. This engine is intended as a substitute for the steam engine, and is actuated by the inflammation of hydrogen gas, which by its combustion in a vessel containing a portion of atmospheric air, sufficient for the combustion of the hydrogen. The oxygen of the air, then combining with the hydrogen, together form water, which of course occupying a less space than these in their original form, leave in the vessel a partial vacuum, the nitrogen of the air, and the impurities of that and the hydrogen gas only remaining. This vessel is made to communicate with the working cylinder, and the pressure of the atmosphere then acting on the piston, puts it in motion, which motion is continued until the equilibrium is restored, between the interior of the aforesaid vessel and the external atmosphere. But by using two of such vessels, and repeating the process of inflammation alternately on each, so that one of them may be giving motion to the piston, whilst the other is having its vacuum restored, the working part of the engine may be constantly kept up.

The principle of forming a vacuum by these means, has been long familiar to every one, the following simple experiment being one which, we doubt not, each of our readers will remember to have heard when a child. Take a wine, or any other glass, small enough to be covered on the top by the palm of the hand, and having placed a small piece of lighted paper on the middle of the palm, (taking care to protect the hand from being burnt,) then covering the burning paper with the mouth of the glass, by pressing the latter against the hand, a partial vacuum is instantly formed, (by the combustion of the oxygen of the air in the glass,) sufficient not only to prevent the glass from falling, when the palm of the hand is turned downwards, but such as to require some little force to remove it from its hold. If this experiment be dexterously performed, it will perhaps give some pain to a delicate hand, from the great force with which the pressure of the atmosphere presses the flesh into the glass.

Mr. Brown's engine is a modification of this principle, and will, we doubt not, be fully understood by the following description.

* Register of the Arts, vol. iii. pp. 114-17.

Inflammable gas is introduced along a pipe into an open cylinder or vessel, whilst a flame placed on the outside of, but near to the cylinder is constantly kept burning, and at times comes in contact with and ignites the gas therein; the cylinder is then closed air-tight, and the flame is prevented from communicating with the gas in the cylinder. The gas continues to flow into the cylinder for a short space of time, then it is stopped off; during that time, it acts *by its combustion* upon the air within the cylinder and at the same time a part of the rarified air escapes through one or more valves,—and *thus a vacuum is effected.* The vessel, or cylinder, is kept cool by water. Several mechanical means may be contrived, to bring the above combination into use, in effecting the vacuum with inflammable gas; and on the same principle it may be done in one, two, or more cylinders or vessels. Having a vacuum effected by the above combination, and some mechanical contrivance, powers are produced by its application to machinery in several ways. First, water-wheels may be turned; secondly, water may be raised; and, thirdly, pistons may be worked.

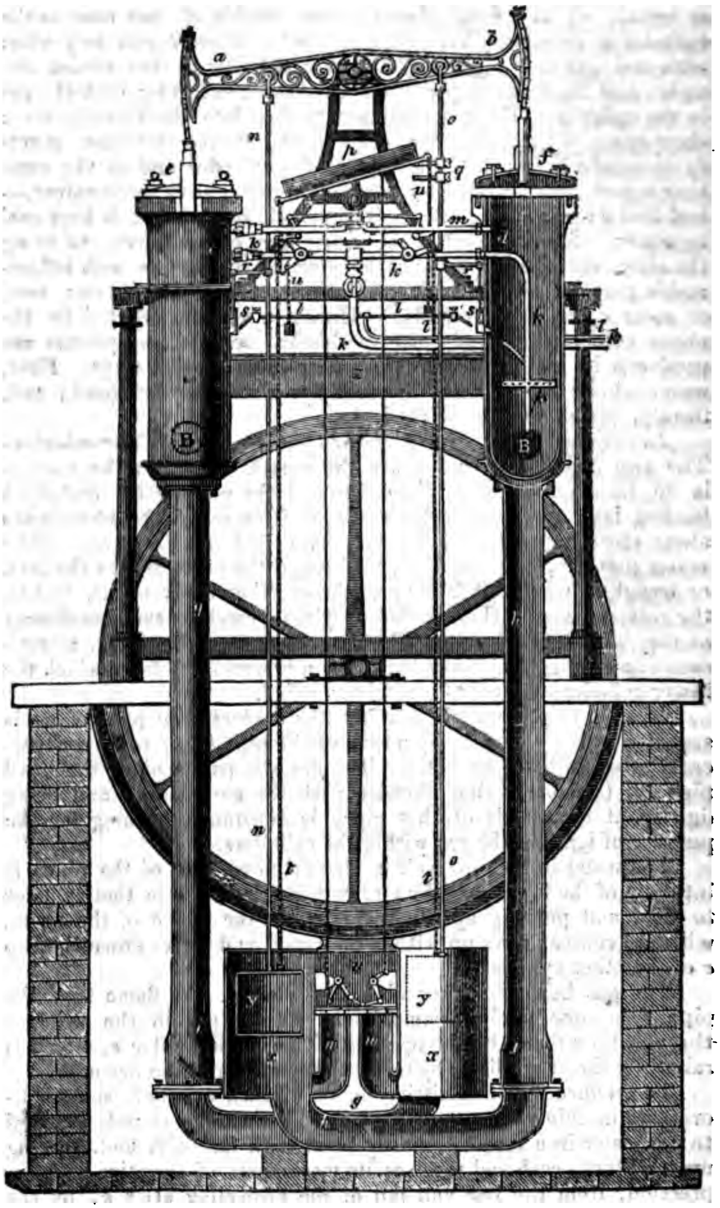
Description of the Engine as used for turning a Water-wheel.—The two cylinders *c* and *d* are the vessels in which the vacuum is to be effected; from these descend the pipes *g i g* and *h j h* leading into the lower cylinders *x x*, from which the water rises along those pipes to fill the vacuum cylinders alternately. The water thus supplied is discharged through the pipes B into the tank or trough *s*, whence it falls upon the overshot water-wheel, and by the rotatory motion thus produced, gives power to such machinery as may be connected to it. The water runs from the wheel, along a case surrounding the lower half, into a reservoir *v*, from which the lower cylinders *x x* are alternately supplied.

In order to produce the vacuum, the necessary quantity of gas is supplied to the cylinders by means of the pipe *k k k*, to be conveniently attached to a gasometer. The gas also passes along the small pipe *l l*, (communicating likewise with the gasometer,) and being lighted at both ends of that pipe, is constantly burning for the purpose of igniting the gas within the cylinders.

The water in the reservoir *v* passing down one of the pipes *w* into one of the lower cylinders *x*, causes the float *y* in that cylinder to rise, and pushing up the rod *o* raises the end *b* of the beam, which of course draws up with it the cap *f*, and forces down the cap *e* of the other cylinder *c*.

The gas being admitted along the pipe *k*, the flame from the pipe *l* is now freely communicated to the gas in the cylinder through the orifice, by the opening of the sliding valve *s*, which is raised by the arm *r* lifted by the rod *o* by means of the beam.

To produce the intermitting action of each cylinder, some subordinate machinery is put in operation, by chains and rods attached to a glass or iron vessel *p*, partly filled with mercury, and, turning upon a pivot, each end receives its movements of elevation and depression, from the rise and fall of the projecting arms *q*, by the action of the beam above; the mercury being furnished for the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purpose of regulating the supply of the gas into the cylinders, and the movement of the slide in the trough *v*. By the action thus communicated, the water from the reservoir flows down the pipe *w* into the vessel *x*, and produces the elevation of the float *y* and the rod *n*, and raises the cap *e* by the ascent of the beam at *a*.

The motion thus caused in this part of the machinery, operating upon its duplicate parts on the other side, of course produces by its action a corresponding movement; and the slider in the trough *v*, moved by the action of the mercurial tube *p*, being removed from its position, allows the water to fall into the other pipe *w*, and as it ascends suffers the float *y* to descend, and rising into the main cylinder, thus lifts again the beam at *b*, and its connections, and forces down the cap *e* on the top of the other cylinder.

After the vacuum is effected in the cylinders, the air must be admitted to allow the water to be discharged and the caps to be raised: this is accomplished by means of a sliding valve in the air pipe *m m*, acted upon by chains *t t*, attached to the floats in the reservoir, and as motion is given to them the valve is made to slide backwards and forwards, so as to allow of the free admission of atmospheric air.

Chains *u u* with suspended weights open the cocks in the pipe *k k*, and produce the alternate flow of the gas, and regulate and modify its supply.

In the pipes *g i g* and *h j h* are clacks to prevent the return of the water when the air is admitted into the cylinders.*

When pistons are worked, the vacuum is effected (in the manner above described) under the piston, which is then pressed down by the weight of the atmosphere, and as an engine of that description is worked with two cylinders and pistons, the vacuum being produced in each cylinder alternately, the fall of one piston raises the other, and, being alternately pressed down, the piston rods give motion to the crank and fly-wheel. The air is admitted through large valves in the piston, and through orifices in the cylinders. An engine may be worked with one piston, the vacuum being produced in two cylinders (as in the water engine), from which a pipe communicates with a third cylinder in which the piston works, and into which the air is admitted alternately under and over the piston, while the vacuum extends to its opposite sides. By this contrivance a much greater rapidity of motion may be given to the piston if required.

The ways being therefore explained, in which, by the pressure of the air, the vacuum produced (and continued) is applied to useful purposes, Mr. Brown claims to be the inventor of the combination above described for effecting a vacuum, *however much* it may be *varied* by the *mechanical means* with which it may be used, and also the inventor of applying a vacuum produced by the *combustion* of inflammable gas, to raising water, and to the production of motion in machinery by the pressure of the atmosphere.

The different scientific journals were much divided, as to the

* Register of Arts and Sciences, vol. i. p. 337.

result of Mr. Brown's experiments: not that any one questioned the effective operation of an engine on this principle, that having been clearly established by actual construction, soon after the publication of the scheme; the question simply being, whether the apparatus could be purchased and maintained, at a less or at a greater cost, than the steam on the most approved construction. It would be needless to repeat the various inquiries on this subject, nearly all of them having been merely theoretical, and some of them written by persons, unable to calculate from all the facts of the case. We have before us the report of a committee, appointed by the shareholders of a company called the "Canal Gas Engine Company," formed expressly for the purpose of trying on a large scale, and if practicable, of bringing into general use, Mr. Brown's engine. Mr. Routh, a director, stated that "They had been appointed to ascertain the practicability of Mr. Brown's engine, for the application of gas instead of steam, to the propulsion of vessels either on canals or navigable rivers. Two experiments had been made; the one on the 1st of January, and the other the day previous, under the inspection of the committee. The gentlemen who were entrusted to examine and report to the shareholders, differed greatly in their opinions derived from those experiments; but they were now ready to state their individual opinions on the subject, which was certainly one of great national importance. The day on which the first experiment was made, being extremely boisterous, was particularly unfavourable to the performance of the experiment, inasmuch as the boat itself was leaky, and the machinery defective. The boat then made way, but not in such a manner, as to give a highly advantageous opinion of the powers of the engine. In the second experiment, however, it was in a more perfect state. The boat, which was started from Blackfriars Bridge, went at the rate of from seven to eight miles per hour, with all the regularity of steam boats; the paddles moved as regularly; and it appeared the power of the engine might be sustained for any length of time by gas, as well as by steam. It was the opinion of most persons there, that the engine answered every purpose expected of it; and he owned, that, as far as power went, it was his own opinion. But he considered that the expense of procuring gas would entirely prevent its application as a prime mover instead of steam.—It was said that gas could be readily and cheaply procured by the decomposition of water. We understood the chairman to express himself of opinion, that this proposition had not been yet made out. He was decidedly of opinion that the company ought to be dissolved. In fact, it was impossible that it could go on. The sum of rather more than £5000. had been subscribed. £1000. had been given to Mr. Brown, for the share of his patent right in the invention; £1000. more had been paid for constructing an engine, under his superintendance, for the application of his principle, which had failed. There was £1700. locked up in the hands of their bankers, Sir John Perring and Co. Then £300. was paid for a boat, and the remaining available funds were otherwise absorbed. The company could not,

therefore, proceed without another call, which could not of course be made, or, if made, attended to."

On the other hand, it was stated by Mr. Brown, "that the experiment had succeeded to the full extent contemplated by himself and friends. On the first time of the experiment, the engine itself was not got into any state of completeness, until the midnight preceding the morning of trial, and they accidentally run the boat on shore, and stove in her side. They had to make the experiment on a boisterous day, and before this accident was repaired, the paddle-wheel was found to be too small, and deficient in power. A second experiment was made on the river, before the Lords of the Admiralty and a number of scientific men, and the result was such as to decide their minds in favour of its eligibility. He would state further, that it would, without doubt, be adopted."* He did not, however, shew by figures or any other calculation, that gas could be obtained at such a cost, as to allow a fair competition with the steam engine: and we are therefore inclined to give full credit to the statements of the chairman and directors, namely, "*that the expense of procuring gas, would entirely supersede its application as a prime mover instead of steam.*"

Previous to the year 1823 carbonic acid had never been exhibited but in the gaseous or aeriform state, and it was a commonly received opinion, that no degree of pressure or of cold would cause it to assume a more concentrated form; in the early part of that year, however, Mr. Faraday of the Royal Society, under the direction of its illustrious president, Sir H. Davy, succeeded in reducing it (as well as several other gases) into a liquid state, by the mechanical pressure of a condensing pump.

This liquid, at the temperature of freezing water, in its endeavour to assume the aeriform state, exerts an expansive force equal to 30 atmospheres; at ordinary temperatures, a force of from 40 to 50 atmospheres; and on a heat of only 120° Fah. being applied the force is increased to 90 atmospheres; the pressure increasing in a similar ratio for higher degrees of heat; in other words, at the rate of about 11 or 12 pounds increased pressure upon the inch, for every single additional degree of heat.

To construct an apparatus by which a power so immense, and apparently so economical, might be rendered available, like the steam engine, as a first mover to all kinds of machinery, we may easily conceive has occupied the attention and study of many of the most scientific and clever men, not only of this, but of every country in the civilized world; since it cannot be doubted that the paper of Sir H. Davy, "*on the application of liquids formed by the condensation of gases as mechanical agents,*" has been published every where, and translated into the languages of all countries where mechanics is studied as a science. Nearly four years have intervened since the publication of the important facts detailed in the paper alluded to, during which period, not only individual talent, but the abilities of

* Public Ledger.

one of our first chemists have been united with those of one of our most eminent engineers for the accomplishment of this great desideratum. In this honourable spirit of rivalry, the talents of Mr. M. I. Brunel have been employed, and notwithstanding the attention requisite to his other great works now in progress, he has found the time, and the means, by a few simple and admirable combinations, to outstrip in the career all his contemporaries; and to present to the world the first carbonic acid or expansive gas engine.

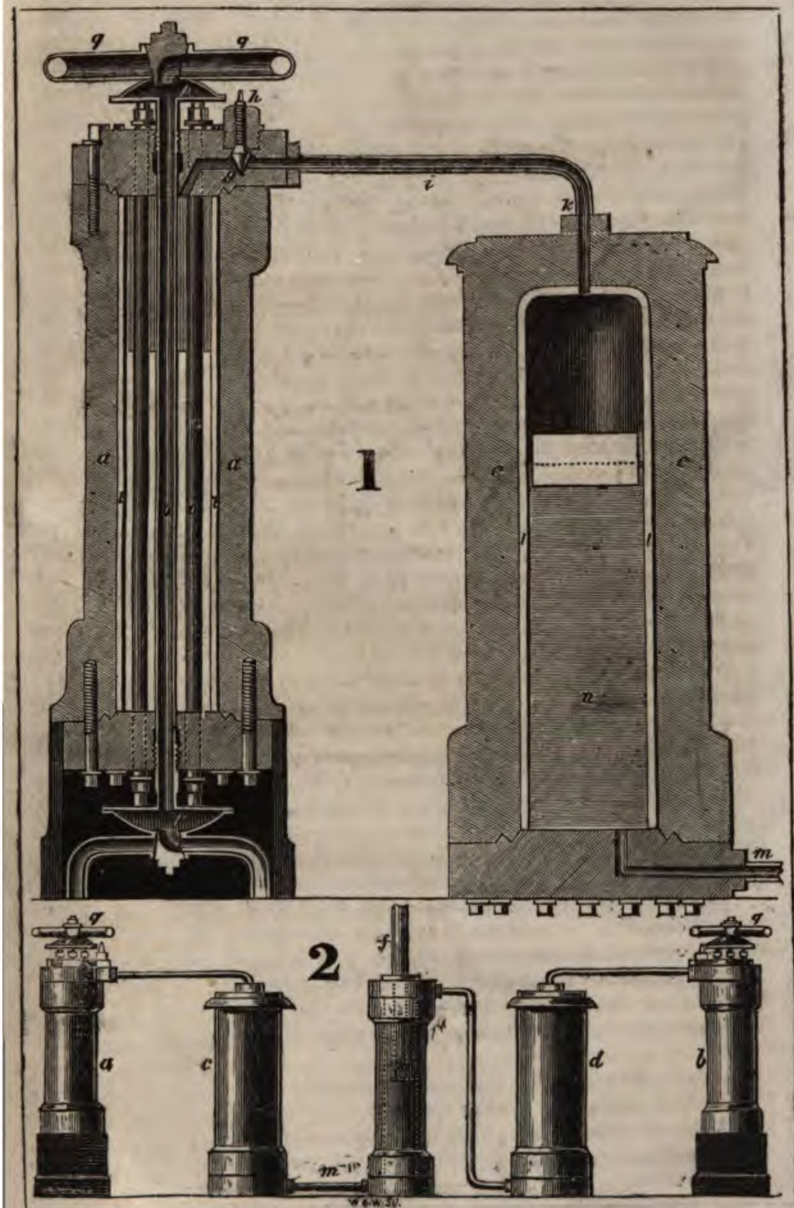
It is proper that we should here remark, that the patent right for Mr. Brunel's apparatus is not limited to the employment of carbonic acid, but that it extends to all liquids which are the result of the condensation of the gases. The preference being however given to the former, we may perhaps infer that the engine we have to describe, is better adapted to the peculiar properties of carbonic acid gas, than to those of the others. Carbonic acid gas may be obtained by decomposing any of the carbonates by the action of the common acids. The mode of obtaining the liquid from the gas, is by forming the gas under a gasometer, and condensing it afterwards in another vessel by means of a condensing pump, and continuing the operation until it passes to the liquid state.

The apparatus, as shewn at fig. 2, consists of five distinct cylindrical vessels; the two exterior vessels *a* and *b* contain the carbonic acid reduced to the liquid form, and are called the *receivers*; from these it passes into the two adjoining vessels *c* and *d*, termed *expansion vessels*; these last, having tubes of communication with the working cylinder *e*, the piston therein (shewn by dots) is operated upon by the alternate expansion and condensation of the gas, giving motion to the rod *f*, and consequently to whatever machinery may be attached thereto.

As the working cylinder *e* is of the usual construction, no further description of that part of the apparatus is necessary; and as the wo vessels on one side of the cylinder, are precisely similar to those on the other, a description of the receiver *a*, and the expansion vessel *c*, will apply to their counterparts *b* and *d*; the two former, (*a* and *c*) are therefore given in a separate fig. (1) on a larger scale, in section, that their construction may be seen, and their operation better understood. The same letters of reference designate the like parts in both figures.

The communication of the condensing pump (before mentioned) with the receiver *a*, is through the orifice *g*, which can be stopped at pleasure by the plug or stop cock *h*. When the receiver has been charged with the liquid and closed, a pipe *i* is applied to, and connected to the expansion vessel *c* at *k*. *l l* is a lining of wood (mahogany) or other non-conductor of heat, to prevent the absorption which would otherwise be occasioned, by the thick substance of the metal. The expansion vessel is connected through a pipe *m*, to the working cylinder *e*; these vessels contain oil, or any other suitable fluid, shewn at *n*, as a medium between the gas and the piston.

The receiver is a strong gun-metal vessel, of considerable thickness, in the interior of which are placed several thin copper tubes,

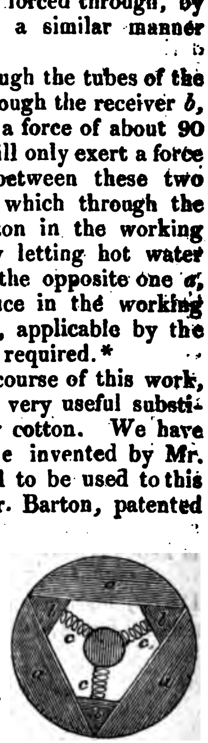


see p. 200.

as represented at *o o o*; the joints of these tubes, through the top and bottom of the receiver, are made perfectly tight by packing. The use of these tubes is to apply alternately, heat and cold to the liquid contained in the receiver, without altering very sensibly the temperature of the cylinder. The operation of heating and cooling through the thin tubes *o o o*, may be effected with warm water, steam, or any other heating medium; and cold water, or any other cooling medium. For this purpose the tubes *o o o* are united by a chamber and cock *p p*, by the opening of which, with the pipes *o o*, hot and cold water may alternately be let in and forced through, by means of pumps, the cocks being worked in a similar manner to those in steam engines.

Now if hot water, say at 120°, is let in through the tubes of the receiver *a*, and cold water at the same time through the receiver *b*, the liquid in the first receiver will operate with a force of about 90 atmospheres, while the liquid in the receiver *b* will only exert a force of 40 or 50 atmospheres. The difference between these two pressures will therefore be the acting power, which through the medium of the oil, will operate upon the piston in the working cylinder. It is easy to comprehend that, by letting hot water through the receiver *b*, and cold water through the opposite one *a*, a re-action will take place, which will produce in the working cylinder *e*, an alternate movement of the piston, applicable by the rod *f*, to various mechanical purposes as may be required.*

We have mentioned more than once in the course of this work, that metallic pistons have been considered as a very useful substitute for those which are packed with hemp or cotton. We have already given, at page 76, a description of one invented by Mr. Cartwright, which, as we observed, is continued to be used to this day. We are now about to describe that of Mr. Barton, patented in 1818, and explained as follows.



The annexed figure gives a horizontal section of Mr. Barton's piston. It is composed of three segments *a a a*, forming together a circle, they are made either of brass, or cast steel, hardened and tempered. These segments are preserved in their places by three triangular metal wedges *b b b*, which act equally upon them by the pressure of three strong helical springs *c c c* working over three steel pins (not shewn). When the segments become worn, the wedges are protruded forward by the force of the springs, and fill up the space they would otherwise leave unoccupied; by which a perfectly close contact is uniformly preserved for a very considerable period of time.

On the exterior or periphery of the circle formed by the segments and wedges, three grooves are made all round; the upper and lower are to contain two metal rings with a cleft across each, which just fit flush into them; these serve to keep the several parts together,

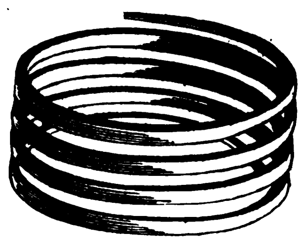
* Register of Arts and Sciences, vol. iii. pp. 258-60.

so as to prevent any displacement in putting in or taking out the piston from the cylinder. The middle groove is for the purpose of holding grease or oil to lubricate the piston and cylinder.

Mr. Barton has succeeded in bringing this kind of piston into use somewhat extensively, and has obtained the certificates of several respectable persons, as to its effectiveness and utility: from among these, we quote the authority of Messrs. Thornhill and Morley, of New Bond Street, who state, that previous to the adoption of Mr. B.'s piston, they required the steam to be raised in the boiler, to the pressure of 73lbs. on the inch; but that since that time, their engine can do more work with the steam at 43lbs. only, and that during three years they had not a single stoppage, as it continued perfectly tight.

The objection which is urged against this piston is, that the wedges *b b b*, advancing forward as they become worn, quicker than the segments *a a a*, there will be a tendency in them to cut grooves in the cylinder, by their points constantly working up and down, or that if they should not produce this effect, then they will be prevented (by the resistance of the cylinder) from forcing out the segments, so as to keep them tight against the sides, and thereby prevent the steam from escaping past them. It is also contended, that as the segments are worn away, they will not fit closely to the circle of the cylinder, because the curvature of a small circle, never can be in contact with that of a larger, excepting in one point. In reply to these objections, the inventor appeals to the actual experiment, and certainly it appears that practice has not warranted these conclusions, it being found, that those points which are most forcibly pressed against the cylinder, are soonest worn away, and therefore, that the points of the wedges, and those parts of the segments which are most forcibly pressed against the cylinder, are sooner removed by this self correcting process; so that the whole is kept perfectly circular, and in close contact with the cylinder.

A patent was also obtained by Mr. William Jessop, of Butterley, Derby, for a metallic piston, which is formed only of one piece, of a spiral figure, as below.



The piston is first to be bound round with hempen packing, as a bed for the metallic portion, and to prevent the escape of the steam. The spiral spring is placed between the upper and lower plates of the piston, through which screw bolts are passed, and by turning the

nuts, the plates are brought nearer to one another, and the metallic coils are thereby pressed closely together. Thus restrained above and below, the metallic coil is to expand and contract laterally against the sides of the cylinder, and while it shall effectually prevent the escape of the steam, to press with the requisite force, uniformly, so as to produce very little friction.

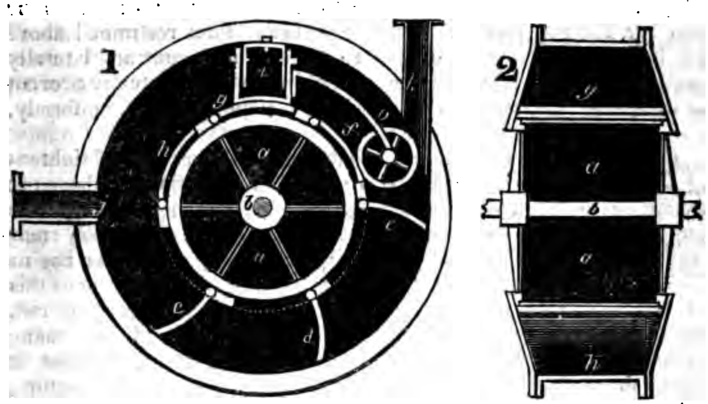
On this plan it may be said, that though the method of tightening the packing as it wears, is simple and easy, yet it does not obviate one of the objections against hempen packing, namely, the danger that a careless, or even an experienced workman, may screw it down so tight, as that nearly all the power of the engine will be absorbed by giving motion to the piston. Though perhaps this will appear a matter of trifling importance, as it will be answered, that such a fault can be easily corrected, yet it is found, that many enginemen are extremely careless on these matters, so that it is desirable, if possible, to have the piston of such a construction, as to be entirely out of their power. However, in the hands of an ingenious and attentive engineman, these pistons are found to be very useful and economical.

A great variety of forms have been given to the metallic piston; generally, however, they partake in some degree, of the principles of those described.

A patent was obtained in 1823 for a Rotative Engine, by Messrs. Beningfield and Beal, of London, which resembled in principle those of Messrs. Cartwright, Malam, Routledge, and Chapman. It differs, however, from most of these in some points, namely, that its external cylinder revolves whilst the interior one is stationary, and the motion is communicated to the machinery by a spur wheel on the cylinder working into another spur wheel on the shaft. The internal arrangements of the engine approach nearest to Chapman's (page 150) of any of the above engines, the difference being that the leaves or valves are fixed to the exterior cylinder, and the piston or steam stop to the interior cylinder. There are many ingenious contrivances for the simple working of the different parts, and for keeping the whole apparatus steam-tight without much friction; and judging from the small engine which we have frequently seen in operation, and which has been working for nearly three years at the manufactory of Beningfield and Co. we are inclined to judge more favourably of this rotative engine than any we have yet noticed. On a small scale there is no doubt of its utility, and we can see no reason why a large engine should not be found effective.

Captain Walter Foreman, of Bath, obtained a patent in 1824, for a Rotative Engine, which is thus described.

Fig. 1 is a side view of the steam wheel, with the casing removed to shew the situation and construction of the valves, and their mode of action in the steam-way. *a a* is the steam wheel revolving upon its axis *b*. *c d e f g h* are six flap valves, having steam-tight joints, and fixed to six blocks on the periphery of the steam wheel; three of the valves are shewn open, and three closed. *i* is a fixed stop for arresting the course of the steam; it is composed of an upper and



lower piece accurately fitting the sides of the chamber, and connected together by means of screw bolts, so contrived as to admit of an easy adjustment when the lower curved surface may become worn, by the friction of the periphery of the steam wheel in its revolution. *o* is the anti-friction roller fixed to a springing curved arm, and screwed to the stop *i*.

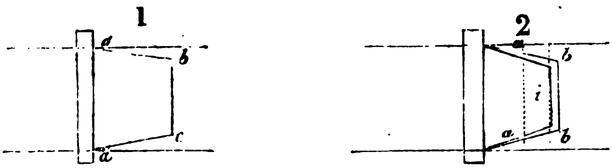
Fig. 2 is a vertical section of fig. 1 through the axis; *a a* the steam wheel, *b* the axis, *g h* two valves, by which is seen their tapering figure, and the conical form of the casing which encloses them; the lower valve is shewn as closing the steam-way, and the upper one as leaving it open, It will now be perceived that the valves from this peculiar shape do not, when moving backwards or forwards, even touch the sides of the casing, consequently all friction in those parts is obviated; the dotted lines in the upper valve, are intended to illustrate this observation, as they describe the course of the extreme edge of the valve, when in the act of opening or shutting the steam-way.

The mode of operation with this engine is as follows: steam as admitted by the tube *j*, which immediately fills up the space between the stop *i* and the valve *c*, and the latter yielding to the expansive force of the vapour, gives motion to the wheel *a a*; when, in the revolution, the valve *h* takes the place of *c*, the flap of *h* (swinging upon its joint) falls by its gravity into the same position; the steam then acts against it in like manner as *c*, and successively the valves *g f e d* in rotation, as fast as the wheel revolves, the steam finally escaping at the pipe *k*; the friction-roller *o* pressing down each flap, as they pass under its operation against the periphery of the steam wheel.*

The only novelty in this engine is the form of the valves, which are not rectangular like those of other rotative engines on a similar principle, but taper outwards. The reason of their being of this

* Register of Arts and Sciences, vol. iii. p. 217.

form is, that there may be no friction from their sides rubbing against the lids of the cylinder, except when they are opened out as at *c d e c* and further, that as they become worn it is calculated they will still continue tight, because all the three bearing sides will, by being a little further opened, press upon the several surfaces over which they pass, and so continue to be steam-tight. Though, perhaps, a valve of this form, acting in a circular channel of the shape here given, may continue steam-tight for a great length of time, yet it unfortunately happens that a leakage is produced in another way by the wearing of these valves, as great, if not greater than could have been by the wearing of rectangular valves.

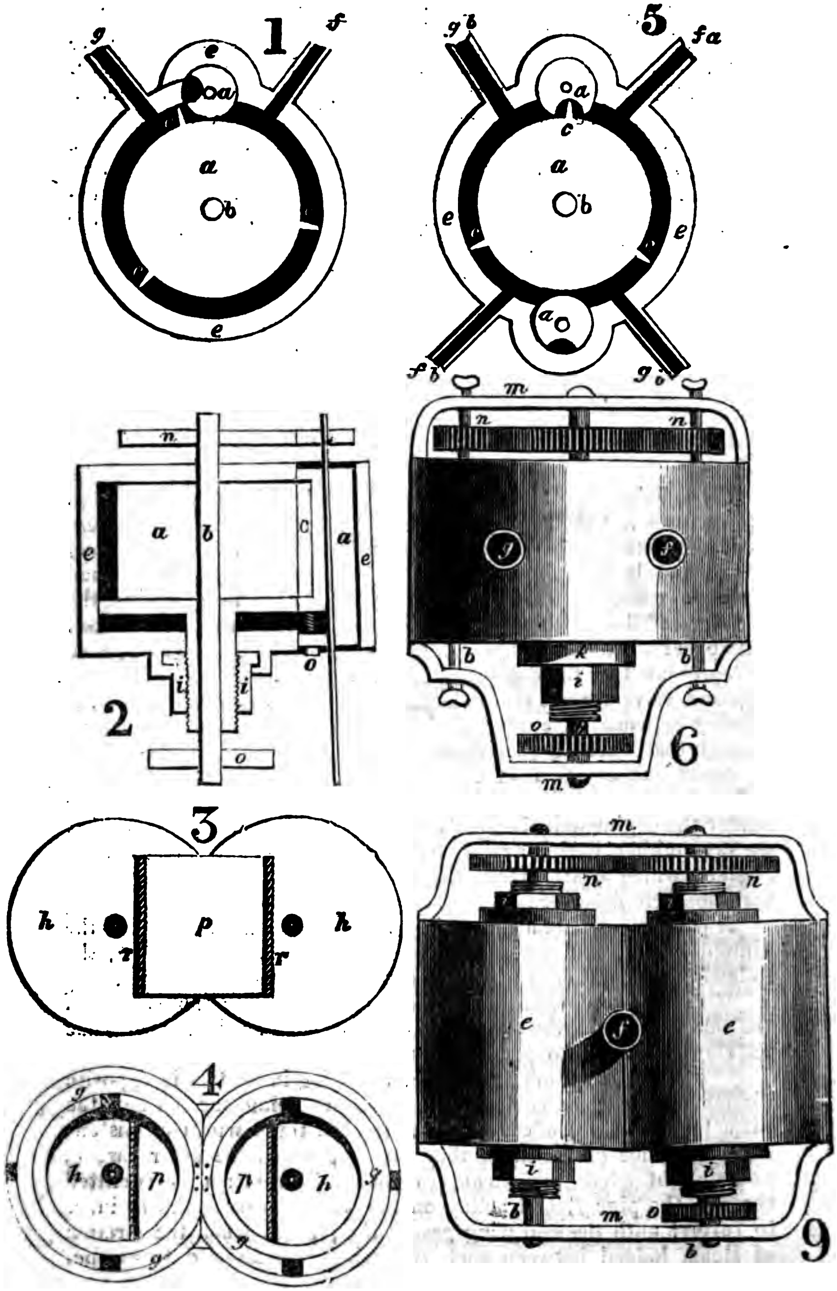


These valves must, in order to pass under the steam stop, fall into recesses in the interior cylinder of the form of fig. 1, and if very accurately fitted to the sides of the recess (a very difficult operation) may at first be tolerably steam-tight, but by the continued wearing of the three working sides of the valve, *a b*, *b c*, and *d e*, against the cylinder and lids, the valve then will become too small for the recess, and appear when shut as in fig. 2. Now, supposing the stop, *i*, to be represented by the dotted lines, it will be evident that whilst the stop and valve are, as there shown, the steam can freely enter the opening between the valve and the sides of the recess, and escape through that opening (say from *a* to *b*). Therefore, as there is at all times one or other of these valves under the steam stop, the leakage of course will be constant, and in a short time so great as to render the engine quite ineffective and useless. Of the great friction we say nothing, having already treated of that when speaking of the engines which nearly resemble this in all the points except the variation here described.

A patent was obtained in 1825, by Mr. Joseph Eve, (late of the United States, but now of Liverpool,) for a Rotatory Engine, the following description of which we extract from his specification.

" Fig. 1 presents an end section, fig. 2 a longitudinal section of the said engine, on the simplest manner of construction. The same letters refer to similar parts in all the figures.

" *a a* are the cylinder and cone, revolving in contact in opposite directions, the cone having one groove and being one third of the diameter of the cylinder, which latter has three wings or pistons *c c c*, the ends of which as they revolve, touch the outer case *e*, and do not admit any steam to pass. The steam is admitted through the pipe *f*, and acting on the wing *c*, causes the cylinder to revolve until the said wing passes the pipe *g*, when the stratum of steam lodged between each two wings, is allowed to escape.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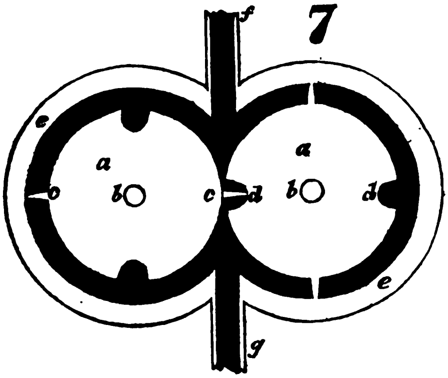
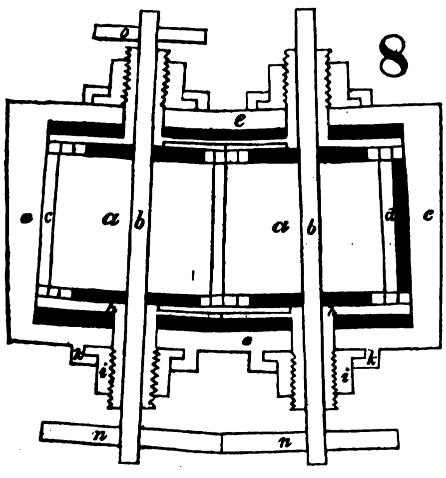




The wing, which has thus passed, falls into the groove *d* of the cone, the bottom of which groove it touches in passing, thus allowing no steam to escape between. The said wing *c* then passes again by the steam pipe *f*, and is acted upon as before described, and so on in rotation. The cylinder *a*, which is firmly fixed to its axis *b*, rests on one side on the outer case *e*, through which the axis projects, but as there is some friction produced by the revolution of the said cylinder at its two ends touching the outer case, I have placed a false end *h h* under the opposite end of the cylinder, which false end slides on the axis *b* freely, and has a thread cut at the end, by means of which and the adjusting nut *i*, the cylinder, if worn at the two ends, can be easily tightened and adjusted. The adjusting nut is confined by the collar *k*, which collar is screwed to the outer case. The conical shape of the small runner, which can likewise be moved upwards or downwards in the outer

case, serves to keep the two convex surfaces of the cylinder and cone in contact.

"The groove *d* in the conical runner, is cut into a separate piece of metal, which slides by an adjusting screw *o* up and down, so that when the engine is adjusted, the groove *d*, on the piece of metal, into which the said groove is cut, can be moved up and down, so as to fit the wings of the cylinder.

"Letters *n n* in fig. 2, present two cog-wheels running into each other, attached on the outside of the engine to the axis of the cylinder and cone, placed there for the purpose of producing a corresponding revolution of the said cylinder and cone, thus causing the groove of the cone to present itself regularly to the wings of the cylinder; *o* is a pinion fixed to the other end of the axis, by means of which any machinery can be put into motion.

"Another variety of constituting a steam engine on this principle is shewn by an end section view in fig. 5, and an external view in fig. 6. This engine has a cylinder with two small conical runners on each side, the said conical runners being of the same construction as before described, with one groove cut into each, and being one third of the diameter of the cylinder. There are two induction and two eduction steam pipes, and, although the engine may be, with the exception of the addition of one of the conical runners, exactly of the same size as the one first described, a double quantity of steam is requisite, and twice the power of the former engine is gained: the steam enters through the pipe *f a*, and acts on the wing *c*, which after having passed pipe *g o* where the steam escapes, falls into the groove *d* of the lower cone, and appearing at the induction steam pipe *f b*, is loaded again with steam pressure, which it discharges at the second eduction pipe *g o*, and then enters the groove of the upper cone, after having passed which it is loaded again at the first-mentioned induction pipe.

"Letters *m m* are bridges, by which the spindles on axis *b b b* are supported. This engine has three cog-wheels *n n n* attached to the three spindles, so as to cause the cylinder and cones to revolve in unison, and like the first described engine, a pinion *o* on the opposite end of the axis of the cylinder. Fig. 7 shows an end section; fig. 8 a longitudinal section; and fig. 9 an external view.

"The two conical runners in this engine are of an equal length and diameter, each has two wings or pistons attached, and two grooves cut into it, and in revolving in opposite directions, the wing of one runner falls alternately into the groove of the other. The steam enters by pipe *f*, and as the cylinders are running in contact, it cannot escape between them, but acts upon the two wings in opposite directions, and escapes at the eduction pipe *g*, after the said wings have passed the same. By reference to fig. 8, which represents a longitudinal section, it will be seen that the two cones have each two false ends *p p*, sliding freely on their spindles; the two outer cases *e e* fit over the runners and their wings exactly, each of the four false ends has an adjusting nut by which the engine is tightened if steam should escape, or slackened if it should run too

tight. Each pair of the false ends, where they join, have a plate that connects them and breaks their joints, so as to prevent escape of steam, this plate *p* slides into the groove *r* cut out of the false ends, as exhibited by fig. 3 and fig. 4, the former showing an end view of the false ends with the connecting plate in the middle. On these false ends packing rings, *g g g*, which are confined to the sliding plate as exhibited in the latter figure, are placed. These rings press against the hollow outer cases, and prevent any steam escaping by them. These packing rings are shown in section, in fig. 8. It will be evident that the false ends need not be made true, if the connecting plates and packing rings as above described, are adopted, and that the engine, if provided with moveable false ends, conical runners, and the afore described connecting plates, and packing rings attached, as shown in fig. 8, can always be kept steam-tight, and by use, the various parts on which there is any friction, will fit better."*

A patent was obtained in 1826, by Louis Joseph Marie, Marquis de Combis, of London, for an improved Rotary Engine, the principle of which is as follows:—

"A piston is made to circulate within a vertical hollow ring, by steam admitted alternately at two opposite points of the diameter of the latter, and discharged through perforations in the central boss of the piston, and in its tubular axis; which hollow ring is separated into two equal portions by sliding valves, that pass across its cavity on to the axle, at its different sides, and which are withdrawn successively as the piston approaches to them, and are instantly replaced as soon as it has passed.

"The form of the case, that contains the hollow ring, may be conceived by supposing a flat cylinder with its angles rounded off, from which rectangular pieces project at opposite sides of its diameter, to contain the sliding valves. This case is divided into two equal portions, by a section through the middle of the axis of its cylinder, and at right angles to it, each of which portions is again divided into two equal parts by another section, that passes in the plane of the axis, and through the midst of the valve receptacles; the four pieces thus formed by the two sections, are united together by screw bolts and nuts, passed through flanches cast on them for their reception. A perforation is made through the middle of the cylinder in the line of its axis; whose diameter is between three and four times greater than that of the revolving axle of the engine that passes through its centre; and at equal distances from it, all round close to the sides of the cylinder is formed the annular cavity, or hollow ring, in which the piston moves.

"The axle of the engine projects a considerable distance beyond the cylinder at each side, to allow space on it sufficient for the reception of the main wheel (by which it gives motion to the machines with which it is connected,) for the fly-wheel, and for the parts that impel the apparatus, which works the sliding valves of the hollow ring, and those of the steam box which communicates with the opposite sides of its diameter. In the middle of this axle is a boss, or

* Register of the Arts, vol. iv. pp. 18-21.

enlarged part, of the full diameter of the perforation of the cylinder; but only of the thickness which is found necessary for an arm, that passes from it to the piston at right angles to the axle, whose breadth regulates its size; and for the revolution of which, along with the piston, a circular cavity is left between the two lateral divisions of the cylinder.

"To make the cavities steam tight at each side of the boss round the axle, there is first a layer of hemp packing put in close to it at each side; secondly, a cylindrical piece is placed over that, round the axle, which closely fills up the whole central perforation through the cylindrical part of the case, in the external portion of which piece a hollow cone is formed, with its apex next the boss, from the top of which ears project at each side, through which screws pass that draw it towards the case, and thereby compress the packing between it and the boss; and, thirdly, a conical piece, perforated to receive the axle in its centre, and ground so as to fit the conical cavity truly, is placed over the hole, and connected by sliding side pieces to the axle so as to turn along with it; while from other pieces, also attached to the axle, screws parallel to it project so as to press it towards the centre.

"The piston (which is called a sole by the patentee) is made steam tight by two layers of metallic packing, (each formed of three segments of a circle equal to it, having three triangular pieces pressed into the angular cavities, formed at their points of junction by helical springs that proceed from the centre,) whose principal pieces are so arranged, that the joinings in one layer are covered by the middle parts of those in the other layer. And the sliding valves that pass across the case horizontally through the hollow ring to the axle are made steam tight at the sides, by fitting closely to the parts of the case through which they pass, and next the axle by a metallic packing pressed towards the latter by springs; and as it is expedient that these valves should be thin, that the piston may pass the cavities through which they slide, with more facility, to give them at the same time sufficient strength, ribs are fixed to their faces in the direction of their motion, for which there are corresponding grooves formed in the projections of the case, into which they are received, which projections extend sufficiently to enclose them at every side, only being perforated opposite the middle line of the slides, to allow of the passage of rods, that proceed from them through stuffing boxes, similarly to piston rods, by which rods they receive their motion.

"To connect the main wheel with the axle, two circular discs are fixed to the latter, so that one of them may be pressed toward the other, by screws from other parts proceeding from the axle; and the main wheel being placed between these discs, with its centre on the axle, is so compressed between them, that it revolves with them, so long as the resistance of the work to which it is applied is less than that caused by the pressure or friction of the discs; but should the former become the greatest from any accidental obstruction, the discs will pass round without moving the main wheel; by which means the destruction of material parts of machinery will be prevented which might otherwise be liable to occur.

"To one of these discs just mentioned, a flat toothed plate is

attached; whose shape and teeth correspond with those of two eccentric spiral toothed cams, one of which is placed at each side of it, and from which connecting bars proceed to crank pieces, that by these cams move forward and retract the sliding valves of the hollow ring, at the proper periods; at the parts of these cams that are farthest from their centres, the teeth are serrated, but at those more centrical, where they approximate to the form of circles, the teeth are similar to those in common use.

"The steam passes from the boiler, that is not described, by a tube furnished with a cock, (by which the passage can be diminished as desired,) to a steam receptacle of a semi-annular form, and of about the same size as the hollow ring, which is placed parallel to this latter. From the opposite ends of this receptacle tubes pass to the hollow ring close to the sliding valves; in which tubes, where they proceed from the receptacle, are fixed other sliding valves, called cocks by the patentee, which are moved by a system of crank levers and connecting bars, something similar to that used for the valves of common steam engines, which receive their primary impulses from arms attached to the axle of the steam engine in such a manner, that the times and degree of their impulses may be varied so as to diminish or increase the quantity of the steam admitted to the engine, by a little apparatus fixed to the axle, which could not be well explained without a drawing.

"These valves of the steam tubes, and the larger slides of the hollow ring, are moved so, by the means described, that as soon as the piston passes one of the latter and it becomes closed, the steam tube, that enters the hollow ring close to this slider and between it and the piston, is opened, and the tube at the opposite side becomes closed, which latter, in its turn, becomes opened as soon as the piston has passed it and the slide at the side close adjoining.

"The steam, after passing out from the hollow ring through the perforation in the boss and the tubular passage in the axle beforementioned, enters a condensing vessel where the greatest part of it is condensed into water, and through a spiral tube or worm in the vessel, runs from thence by a pipe into a closed reservoir, which communicates with the bottom of the pump that supplies the boiler; to which pump also another pipe rises from the cold water well, which being below the level of the reservoir, the water only ascends from it, when the latter is empty; and when the boiler is sufficiently full, the pipe of supply is closed by the rising of a balanced floating weight. This pump is worked by a revolving crank, that communicates with the main axle, and which turns in a horizontal slot in a piece attached to the top of its piston rod.

"An open oil vessel is placed at the top of the hollow ring, from which a pipe passes into it that is closed by a cock made to turn round very slowly by a pinion attached to it, in which another pinion works; whose axis extends to one of the discs on the main axle where a wheel is fastened to it, into which a pin projecting from the disc strikes once in each revolution of the latter, and moves it forwards the extent of a single tooth."*

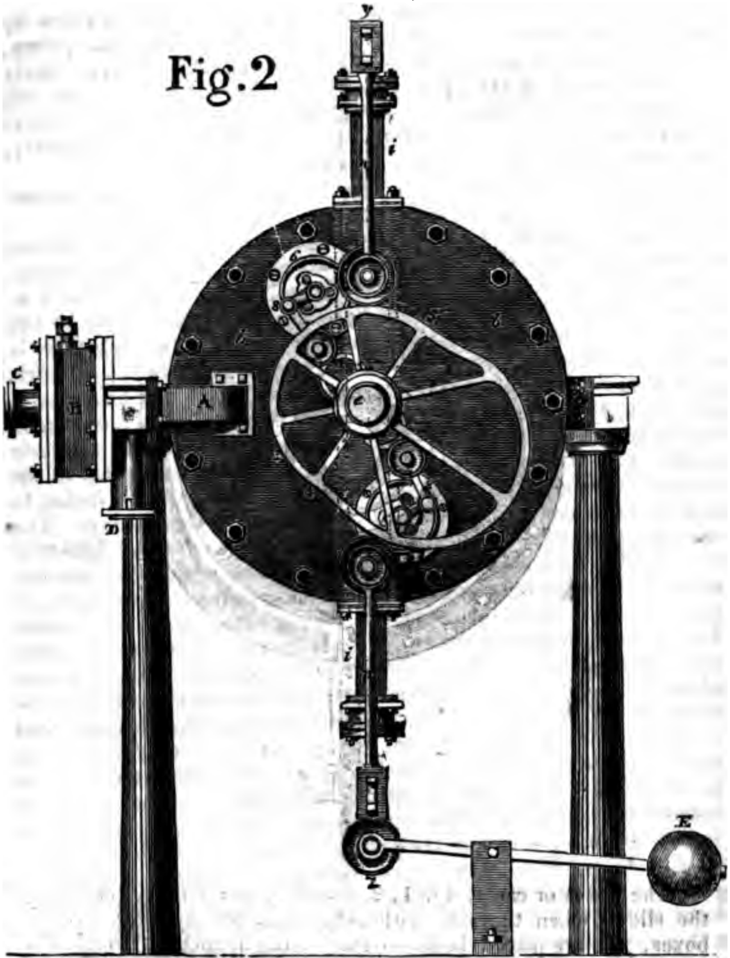
* Repertory of Patent Inventions, vol. iv. pp. 240-1.

This engine comes nearest in its principle, to that patented by Mr. Joseph Turner in 1816; the form of the sliders and piston, together with some of the interior arrangements, being nearly similar. Some of the improvements are very ingenious, and, on the whole, perhaps there is less liability to waste of steam: but it is our fear, that the great objection to many rotary engines, namely, the striking of the sliders, will remain here in full force.

We now come to describe the rotative for which the author obtained a patent in December, 1826.

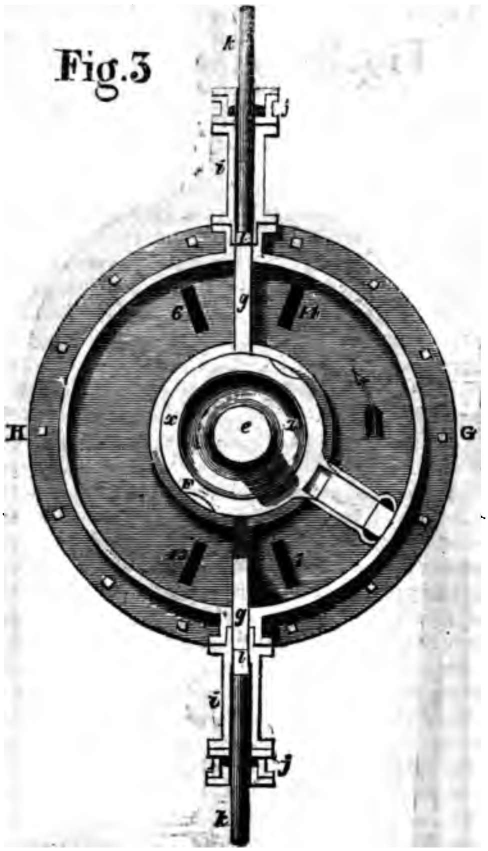
Figure 1, see Frontispiece, represents an elevation of the exterior of this rotary engine. Fig. 2 represents an end view: Fig. 3 represents a section of Fig. 2: Fig. 4 of Fig. 1. *a a*, Fig. 1, 3 and 4, is the cylinder, being accurately bored in the same manner as the cylinder of other steam engines, excepting that at the two ends there is a rabbet. The flanges are also turned rectangularly to the cylindric part, so as to be quite smooth and true on their faces. The lids or caps, *b b*, (1, 2, 3), are turned on their flanges also, they are then turned flat from *e* to *f*. At *f* they project inwards, and form the cylindric bosses *d d*, (also turned), until they nearly meet each other in the interior of the cylinder, leaving only a space of about two inches in large engines, and a proportionably less one in smaller engines. The turned flanges of the lids being ground against the turned flanges of the cylinder form a steam tight joining, which is made additionally secure by the corner or angle of the lid being at the same time ground against the rabbet in the cylinder. On opposite sides of the cylinder Fig. 3, there are two apertures cut quite through of an equal breadth, and extending the lengthway of the cylinder parallel to the axis, and of such a length as to reach about three quarters of an inch over the flat parts *c f*, of the lids. Grooves of a corresponding breadth, and 3-4ths of an inch deep, are cut in the lids from *c* to *f*, in a direct line to the axis. Similar grooves, *f f*, are cut in the bosses parallel to the axis. These are about an inch deep, and of the same breadth as the former. The dimensions of these grooves will be varied, to suit the size of the engine. It is apparent that a section from *y* to *z*, Fig. 2, will pass through the centre of all these grooves. The sliders, *g g*, Figs. 3 and 4, are two plates of metal faced with a thin facing of brass or gun metal; they are of such a thickness as to move freely in their respective grooves, of such a length as to extend from the bottom of the grooves in each lid, and of such a breadth as to reach from the outside of the cylinder to nearly the bottom of the groove *f f*. The purpose of these grooves is to form a bearance for the sliders, which being made smooth and flat, and afterwards ground into their places in the grooves, become steam tight in every part, excepting at the space left between the bosses. Now there is a central plate *s*, (Fig. 3 and 4), which is attached to and revolves with the axis *e e*. This plate is of a thickness sufficient to occupy the space between the bosses, and is kept steam tight by the circular rings 1 1 and 2 2, (placed in recesses turned in the bosses) pressing upon each side of the plate *s*. Underneath each plate is introduced a quantity of hempen or cotton packing, which answers the double purpose of preventing the escape of

Fig. 2



the steam between the ring and its recess, and that the elasticity of the packing, by keeping the ring pressed upon the plate, prevents an escape in that direction. To make the sliders and the central plate form a steam-tight union, small pieces of brass are screwed to the sliders, and thereby allow them to be brought into contact with the edge of the plate, *x*, without permitting any part of the sliders to touch the bottom of the grooves, *f f*. At opposite points of the plate *x*, there is a small portion of the circle cut away, (see F, Fig. 3). The purpose of which is, that the sliders may be moved into their places without noise, for that is produced by the striking of two substances together, and these sliders cannot strike against the bottom of the grooves, nor yet, from the external cam, against the periphery of the plate.

Fig. 3



The boxes or cases, *i i*, 1, 2, 3 and 4, are for the reception of the sliders when they are withdrawn from the cylinder. Stuffing boxes, *j j*, are placed in the middle of the bonnets, through which the rods, *k k*, are worked. These rods are attached to the sliders by means of cross pieces, *b b*, Fig. 3, which are dovetailed and bolted to them: and at the outer end they are keyed to the cross heads, *m m*, 1 and 2, similarly secnred to the rods, *n n n n*, which are forked at the ends nearest to the axis. A small spindle passes through the ends of each fork upon which run three friction sheaves, the larger ones, *o*, Fig. 1, being placed between the forks, and the smaller ones, *p p*, on the ends of the spindle. They are not fixed to the spindle, and therefore may revolve separately and independently of each other.

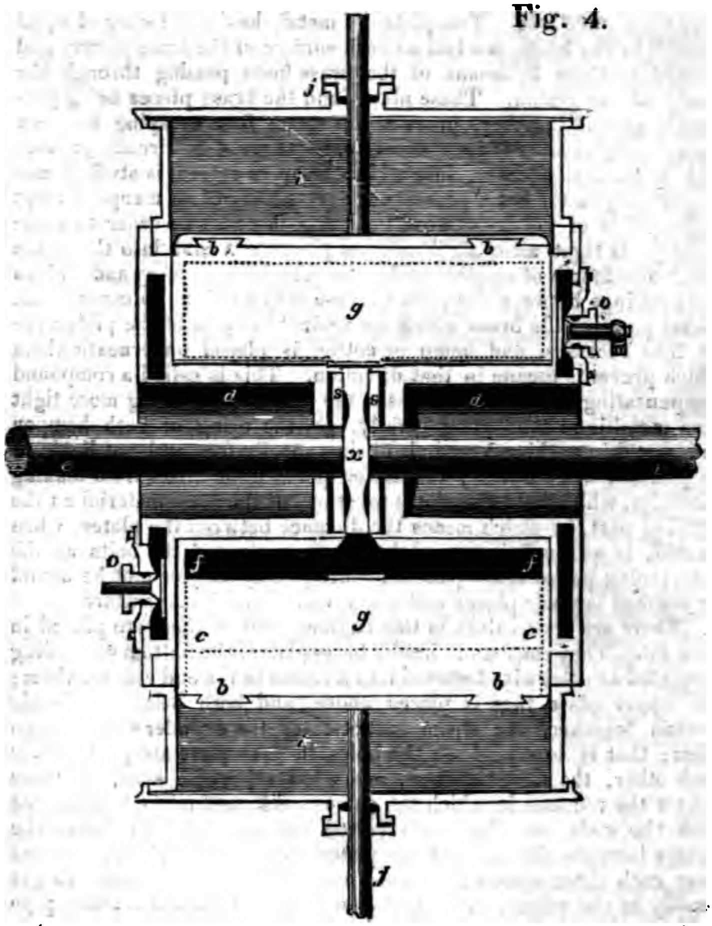
The piston consists of four pieces of brass or gun metal, of about 2½ inches in thickness, filed or otherwise made perfectly smooth, and uniformly thick. Each piece is in the form of the letter L, in the interior of the piston; and spiral springs, acting against an abutment,

force them outwards. Two plates of metal, having a facing of equal breadth to the brass, are laid on each surface of the brass pieces, and pressed on them by means of the brass bolts passing through the whole of the piston. These plates and the brass pieces being previously ground together, prevent the steam from escaping between them; and, as an additional security, there are semi-circular grooves cast in the metal plates, into which hemp or cotton is stuffed, and by pressing on the brass prevents the possibility of an escape, except at the points of union between the brass pieces. In order to make these parts tight also, small overlap pieces are sunk into the brass about one-fourth of an inch, and as the piston wears away and widens the openings between the pieces, these still continue to cover them. Those parts of the brass which are against the arm of the piston are let into recesses, and hemp or cotton is placed underneath them which prevents escape in that direction. This is called a compound compensating piston: it possesses the property of being more tight than metallic pistons are generally, (by the using of both hempen and metallic packing,) and also being equally free and not liable to be jammed when heated; this latter qualification arises from making the bolts, which hold the plates together, of the same material as the wearing part, by which means the distance between the plates, when heated, is as much increased by the expansion of the bolts as the intervening pieces are expanded, consequently they cannot be bound or jammed in their places under any variation of temperature.

There are four valves in this engine; two of them are placed in each lid. They consist of circular brass plates, the bottom ones being cemented or otherwise fastened into a recess in the end cast for them; the upper plate then is placed above, and both being previously ground together, the steam cannot enter the cylinder but through them; that is to say, when the holes in each plate are placed over each other, the valve is open, and when otherwise shut. A plate covers the recesses in which the valves work, and may either be cast with the ends, or afterwards bolted and cemented to them; the spaces between the lids and the plates form circular chambers; and have each three openings; two circular ones, large enough to get readily to the valves, and a rectangular one, to which a steam pipe is attached. Bonnets cover the circular holes, which are thicker in their centres, having a cylindric hole large enough to admit smaller bonnets, O O, Fig. 4, to be placed therein. Spindles previously keyed to the moving plate of the valves are brought through O O to the exterior of the lids. These valves and the spindle are kept steam tight by the screws of O O being turned a little round, which presses the bonnets, O O, in the first instance upon the enlarged part of the spindle, (shown at Fig. 4,) and also upon the face of the fixed valve plate. Small cranks, 8 8, Fig. 2, are attached to the outer ends of the valve spindles, which are connected to the gear, 9 9. Upon this gear are fixed two friction sheaves, which being acted upon by the cam, 01, at proper periods, the cranks, and consequently the valves, are alternately moved to and fro by the revolution of the axis, *i. e.* one of them opening when the other is closing, and *vice versa.*

3 3, Figs. 1 and 3, are two cams, one half of which (namely, from

Fig. 4.



4 to 5) are concentric with the axis, and the other part is the eccentric or cam part, by which the sliders are moved. The motion is produced by the eccentric part acting on the sheaves, *o o*, Fig. 2, and moving them to and from the axis. The smaller sheaves, *p p*, run between guides, (see the dotted lines, Fig. 2,) which preserve a vertical motion to the rods *n n*.

The holes through which the steam escapes and is admitted are placed as near the slider as they can be brought, and are shown for the purpose of illustration, as being all in one lid, at Fig. 3, though, as has been previously stated, there are two in each lid. The effect, however, would be the same were they as represented in Fig. 3; and therefore this mode of explanation will be as clearly understood.

A pipe is brought round, as at A, Fig. 2, into a steam chest, B, Figs. 1 and 2, in which latter is a common slide valve. Into this steam chest the steam is brought from the boiler by the pipe C, and

escapes into the atmosphere or condenser by the pipe D. This slide valve, and the apparatus connected with it, are for the purpose of reversing the motion of the engine.

In order to put this engine in operation, steam is admitted into the steam chest B, when the slide valve is placed in such a position as to allow the steam to enter into one end, and escape at the other, or in other words, when the valves 6 and 7, Fig. 4, are the induction valves. and 14 and 15 the eduction valves; and when the piston and sliders are in the position shown at Fig. 4. The valve, 14, is then open, and communicates with atmosphere or condenser, and the valve, 7, with the boiler; the steam, therefore, entering through 7, rushes against the piston and the upper slider which becomes the abutment against which the steam exerts its force. The piston recedes from the pressure in the direction of the arrow, turning with it the central plate, *x*, the axis, *e e*, the cams, 3, 3, and the valve cams, 01, 01. As the shaft turns therefore, the cam 3, Fig. 2, revolves, and the cam or eccentric part gradually leaves the lower rods, *n n*, and presents the *concentric* part to the sheaves of the said rods. Now the lower cross head being pressed upwards by the counterbalance, E, gradually ascends into the cylinder, so that when the point 4, is in contact with the sheaves of the lower rods *n n*, the slider has then reached its place in the cylinder, being nearly in contact with the central plate F, and also upon its bearance in the grooves before mentioned; the piston will be then at the point G of the cylinder, and both the sliders shut the two valves, 7 and 14 only being open. Now as the piston continues to revolve, the cams 3 3 are gradually opening the upper slider and the cams 10, gradually shutting the valve 14 and opening the valve 15, so that when the piston reaches the valve 15, the former is completely shut, and the latter completely open, and when the piston reaches the upper slider, it is completely withdrawn from the cylinder, and thereby allows the piston to pass it. At this point, the steam is entering through 6, and escaping through 15, the lower slider being then the abutment upon which the steam acts. After the piston has passed the upper slider, the cam 3 allows the piston gradually to return to its place in the cylinder, and after the piston has passed the valve 6, that valve begins gradually to open, and the valve 7 to close. Therefore, when the piston has reached the pipe H, the upper slider is in its seat in the cylinder, the valves 7 and 14 are quite shut, and 6 and 15 quite open: the cam 4 then begins to give motion to the lower slider, as before described, and the cams 10 to the valves, so that a constant rotation of the axis is kept up.

To reverse the motion of this engine, the sliding valve in the steam chest is moved on its face, so that the valves 6 and 7 become the eduction valves, and 14 and 15 the induction valves. Supposing the piston therefore in the position shewn in Fig. 3, and the steam previously entering through 6 and 7, and escaping through 14, it will be seen that if 6 and 7 become the escape valves, and 14 and 85 the induction valves, the steam from the boiler will then rush

through 14 and press upon the piston, and so drive it in a direction contrary to the *arrow*, whilst the steam, before actuating the engine, escapes through 6 and 7, which being shut and opened at their proper time by the cams 10, keep up the rotation in the opposite direction.

The difficulties which have been encountered in the construction of a rotary engine, have been so repeatedly enumerated in the course of this work, that it would be needless to give them here. It will be remembered that great friction, leakage, and the difficulty of maintaining the packing steam tight, have been generally found the great obstacle to the successful adoption of such engines. It is calculated that these objections have been removed, by the author's patent engine. The friction has been reduced in a very great degree, compared to that of the reciprocating engine, the greatest being caused by the revolution of the piston and shaft. The sliders are found to cause scarcely any friction, as they are only moved, when they are surrounded on every side by the same medium; and as the grooves are sufficiently wide, to allow them to move without rubbing against their sides, the only resistance is caused by the rods working through the stuffing boxes. The valves also have the advantage of being only in motion, when they are surrounded by the same medium, and consequently the wear and friction is reduced, considerably below that of the slide of a common engine, which is only moved when under a pressure of steam.

The leakage is found to be considerably less than the leakage of all the engines on this principle which we have hitherto seen. This superiority arises from the use of the compound packing in the piston, by which a great defect in metallic pistons has been obviated. This defect was the difficulty of making the metallic pieces which formed the packing, of an equal thickness, and of bringing them in sufficiently close contact with the plates which enclose them: for it will be seen, that unless the whole of the metallic packing were of an uniform thickness, it would not, when moved out of the situation into which it was at first fitted, fit so closely to the covering plate, and consequently a leakage would take place. By the improved method, however, it is not necessary that the packing should be so carefully constructed, because the elasticity of the hempen packing, would make up for any little irregularity in the metallic part.

The sliders are found also to be much less liable to leakage than the abutment of other rotary engines. This advantage may be attributed to the bearing in the grooves being inaccessible to the piston, or any other part of the machine, except the sliders themselves, and consequently the flat surface originally given to them, is not liable to be destroyed by wear, which is the case with those engines which have leaves or flaps, or even where there are sliders which do not rest entirely in grooves as in the present instance. It is found also that these sliders do not wear out of form, or become leaky, because owing to their vertical motion and the width of the grooves, they can hardly be said to touch the sides of the grooves until they are forced against them by the steam, which only happens when they are at rest.

Not the least evil which the makers of rotary engines have had to contend with, has been the rapid destruction of those parts which have struck each other. Now this is a fault that has invariably existed in all the engines with leaves or sliders. It is however here completely obviated by the mode of bringing the sliders to rest, for instead of allowing them to strike the central plate, a cavity is formed therein at the part where the slider would (but for that cavity) have come in contact with it. The slider therefore can neither touch the bottom of the grooves in the bosses, nor yet the central plate; the external cam work preventing from reaching so far into the cylinder. The edge of the plate and the slider are brought into contact by the circular part of the former, gradually introducing itself like a wedge under the slider after it is at rest, and consequently a stroke is avoided.

In confirmation of the superiority of this engine, we can state, that a small engine of about one horse power, has been in operation for many months, and, is found to possess all those advantages above stated. An engine of fifteen horses power has also been tried at the Iron works of Messrs. Hawks and Co. of Gateshead; in the county of Durham, which drove with ease a tilt hammer, to which a larger engine had been previously applied. The engine was attached by temporary and very defective frame work to the hammer, and in consequence of an accidentally increased resistance of the hammer, the connecting shaft was broken, or rather twisted in two by the power of the engine, although the shaft was calculated as able to sustain a force full one half more than the assumed power of the engine.

Another engine of twelve horses power is now nearly complete, and will in a few days be in operation, in a steam boat on the River Tyne.

We have in this and the preceding chapters, endeavoured to give to the best of our ability, a faithful detail of what appeared to be the most interesting attempts to improve the steam engine. We cannot profess, amongst the almost innumerable patents which have appertained to this subject, to have selected all the very best schemes; but have principally aimed at novelty and ingenuity, though the former may have in some instances, been obtained at the expence of utility, and the latter may have been the effervescence of mis-directed talent. What modification the steam engine may assume, in the hands of those who come after us, is yet undecided, and will be for the future historian to record. Imagination may lead us to speculate, on the possible perfection to which this noble effort of human genius may be brought: but all attempts to set bounds to, or trace the progress of that which is yet in the womb of time, would be as vain as they would be fruitless.

FINIS.

A CHRONOLOGICAL

LIST OF PATENTS,

GRANTED

FOR INVENTIONS AND IMPROVEMENTS OF OR CONCERNING THE

Steam Engine.

1698. Thomas Savery, of London, for raising water by the elastic force of steam; and for effecting a vacuum by condensing steam, to raise water by the pressure of the atmosphere.

1705. Thomas Newcomen and John Cawley, of Dartmouth, and Thomas Savery, of London, for condensing steam under a piston, &c.

1736. Jonathan Hulls, of London, for propelling a boat by steam.

1759. James Brindly, of Lancaster, for a steam boiler.

1766. John Blakey, London, for an improvement upon Savery's engine.

1769. James Watt, Glasgow, for condensing in a separate vessel—using oil, fat, &c. instead of water—casing the cylinder—working engines by the pressure of steam without a vacuum—steam wheel—working engines by the alternate expansion and contraction of the steam.

1769. John Stewart, London, for converting rectilinear into rotative motion.

1772. John Chrysel, London, for an improved furnace.

1778. Matthew Washborough, Bristol, for converting rectilinear into rotative motion.

1781. John Steed, Lancashire, application of the crank motion.

Jonathan Hornblower, Penryn, for an engine with two cylinders.

1782. James Watt, Birmingham, expansive engine—six contrivances for regulating the motion—double acting engine—two cylinders—parallel motion, obtained by a rack and sector—semi-rotative engine—steam wheel.

1784. Ditto, ditto, rotative engine—parallel motions—portable engine and steam carriage—working hammers &c.—improved hand gear—improved method of working the valves,

1785. ditto, ditto, for a furnace for consuming smoke.

1789. Thomas Burgess, London, for converting a vibrating into a rotatory motion.

1790. Bramah and Dickenson, London, for three rotatory engines.

1791. James Sadler, Oxford, rotatory engines.

1793. F. Thomson, London, for an engine with two cylinders.

1794. Robert Street, London, for an inflammable vapour engine.

1796. John Pepper, Newcastle, for saving fuel.

John Strong, Bingham, for a new form of valves.

William Batley, Manchester, for a new mode of working.

1797. E. Cartwright, Middlesex, for a new condensing engine; metallic piston; rotative engine.

J. Grover, Chesham, for a boiler and furnace.

T. Rowntree, London, for a boiler and furnace.

1798. W. Rayley, York, for a furnace, boiler, and appendages.

John Dickson, Southwark, for a method of contraction.

F. Rapozo, (of Lisbon,) London, construction of cylinder and valves.

G. Quieroz, London, for a cylinder and valves.

1799. J. Wilkinson, Castlehead, construction of boiler to save fuel.

M. Murray, Leeds, boiler, damper, horizontal cylinder.
A. G. Eckhardt, for saving fuel.
W. Murdock, Redruth, cylinder—valves—rotatory engine.
James Burns, Glasgow, boiler—saving fuel.
J. Bishops, Connecticut, for a rotatory engine.
1800. Phineas Crowther, Newcastle, crank and parallel motion.
John and James Robertson, Glasgow, furnace to consume smoke—double cylinder.
1801. E. Cartwright, Middlesex, portable engine.
R. Wilcox, Bristol, rotatory engine.
W. Hase, Saxthorpe, cylinder, boiler, &c.
M. Murray, Leeds, pump for the separate discharge of air and water valves—parallel motion.
Timothy Bramah, Pimlico, revolving cock.
G. Medhurst, London, for converting circular into rectilinear motion.
W. Symington, Kinnaird, rotative engine.
1802. Trevithick and Vivian, high pressure engine.
M. Murray, Leeds, portable engine.
T. Saint, Bristol, boiler and furnace.
J. Lewis, Briscombe, improved furnace.
R. Wilcox, Bristol, furnace—boiler—engine.
1803. J. Leach, Merton Abbey, construction of boiler.
Arthur Woolfe, London, improved boiler.
Bryan Donkin, Dartford, rotary engine.
Wm. Freemantle, London, improvement in cylinder, valves, pump.
1804. R. Wilcox, Bristol, improved boiler and furnace.
Arthur Woolfe, London, improved engine—high pressure boiler.
1805. James Rider, Belfast, improvements in cylinder—regulator.
Jonathan Hornblower, Penryn, steam wheel.
Wm. Earl, Liverpool, mode of working and constructing.
James Stevens, London, improved boiler.
Alexander Brodie, London, boiler and furnace.
James Boaz, Glasgow, engine for raising water.
Arthur Woolfe, London, improvements in piston, cylinder, &c.
Ralph Dodd, London, mode of saving fuel.
William Deverall, Blackwall, boiler and furnace.
Samuel Miller, London, various improvements.
John Trotter, London, steam wheel.
Andrew Flint, London, rotative engine.
1806. William Lister, London, rotative engine.
Ralph Dodd, London, various improvements,
R. Wilcox, London, rotatory engine.
W. Miller, London, improved furnace.
1807. Allan Pollock, Glasgow, improved furnace.
Henry Maudsley, London, portable engine.
Ralph Dodd, economising heat.
1808. Thomas Mead, rotatory engine.
James Linaker, Portsmouth, steam boat.
T. Smith, Bilston, certain improvements.
1809. Mark Noble, Battersea, improved engine.
Edward Lane, Stoke-on-Trent, rotatory engine.
J. F. Fesenmeyer, London, peculiar mode of constructing and working.
Richard Leantlebury, Redruth, certain improvements.
Samuel Clegg, Manchester, rotatory engine.
1810. Arthur Wolfe, London, various improvements.
W. Clerk, Edinburgh, regulation of heat.
W. Chapman, Newcastle, rotatory engine.
Richard Witty, of Hull, combination of the reciprocating rectilinear motion, with the rotative—two engines.
Stedman Adam, Connecticut, various improvements.
1811. Richard Witty, Hull, improvements upon former patent.
Charles Broderip, London, various improvements.

W. Good, London, construction of valves.
J. Trotter, London, improved application of steam.
Henry James, Birmingham, steam boat.
1812. John Sutherland, Liverpool, boiler.
R. W. Fox and Joel Lean, Falmouth, various improvements.
Henry Higginson, London, steam boat.
William Onions, Poulton, rotatory engine.
1813. Robert Dunkin, Penzance, improved furnace.
W. Brunton, Butterly, various improvements.
John Barton, London, various improvements.
John Sutherland, Liverpool, furnace.
J. White, Leeds, various improvements.
C. Brodrick, London, improved boiler.
1814. W. A. Noble, improved engine.
J. Rastrick, Bridgenorth, certain improvements.
Thomas Tudal, York, steam carriages.
John Slater, Birmingham, improved boiler.
Dodd and Stephenson, Killingworth, steam carriages.
1815. William Loch, Newcastle, furnace.
H. Holdsworth, Glasgow, certain improvements.
M. Billingsley, Bradford, certain improvements.
Richard Trevithick, Cambron, improved piston—rotative engine.
W. Moult, London, improved furnace.
J. Cutler, London, mode of supplying fuel.
Marquis de Chabannes, saving fuel.
1816. Dawes, Bromwich, improved parallel motion.
G. F. Mantz, Birmingham, furnace for consuming smoke.
Bryan Donkin, Surry, boiler.
Alexander Rogers, Halifax, mode of setting boilers to save fuel.
John Barton, various improvements.
Philip Taylor, Bromley, mode of applying heat.
W. Steinson, Coleford, improved engine.
Robert Stirling, Edinburgh, improved furnace.
George Bodley, Exeter, various improvements.
Joseph Turner, Layton, rotatory engine.
John Neville, London, new mode of generating and applying steam.
Joseph Gregson, London, mode of supplying fuel.
William Losh, Newcastle, improved furnace.
1817. George Manwaring, London, various improvements.
John Oldham, Dublin, steam-boat.
Moses Poole, London, certain improvements.
1811. William Moutt, London, certain improvements.
Alexander Haliburton, Lancashire, improved furnace.
John Scott, Penge, steam boat.
Philip Taylor, Bromley, application of heat.
Munroe and Langton, certain improvements.
Joshua Routledge, Bolton-le-moor, rotatory engine.
William Church, London, certain improvements.
William Johnston, London, furnace consuming smoke.
1819. Marquis de Chabannes, London, boiler of tubes.
Jones and Plimley, Birmingham, certain improvements.
John Malam, London, certain improvements.
Sir W. Congreve, London, steam wheel.
James Frazer, London, junction of tunnels in a boiler.
R. Wright, London, various improvements.
John Seaward, London, mode of generating steam.
William Brunton, Birmingham, revolving furnace to consume smoke.
George Killey, Briggen, various improvements.
John Pontifex, London, improvement on Savery's engine.
1820. John Oldham, Dublin, additions to former patent.
William Carter, Middlesex, certain improvements.
John Barton, London, engines and boilers for propelling.

John Hague, London, various improvements.
John Wakefield, Manchester, furnace and mode of feeding.
William Brunton, Birmingham, additions to former patent.
Josiah Parkes, Warwick, furnace for consuming smoke—and lessening the consumption of fuel.
Job Rider, Belfast, rotatory engine.
John Moore, Dublin, rotatory engine.
W. Pritchard, Leeds, furnace for consumption of smoke.
1821. William Aldersay, Homerton, substitute for the crank.
Thomas Masterman, Ratcliffe, steam and water wheel.
Robert Stein, Lambeth, certain improvements.
Robert Delhap, Belfast, rotatory engine.
Dr. Henry Penneck, Penzance, lessening consumption of fuel.
Henry Brown, Derby, furnace for consuming smoke.
Aaron Manby, Tipton, various improvements.
Thomas Bennet, Bewdley, various improvements.
Sir. W. Congreve, London, improvements on former patent.
Franz. Anton Egells, London, various improvements.
Charles Broderip, London, various improvements.
John Gladstone, Castle Douglas, North Britain, improvements in steam vessels.
Julius Griffith, Middlesex, locomotive steam carriages.
1822. Richard Ormrod, Manchester, mode of setting boilers.
G. H. Palmer, London, furnace for consuming smoke.
George Stephenson, Long Benton, certain improvements.
Alexander Clark, Louchars, Fife, improvements in boilers and condensers.
M. J. Brunel, Chelsea, certain improvements.
Joseph Smith, Sheffield, improved boiler.
John Stanley, Manchester, supplying furnaces with fuel.
T. and J. Binns, Tottenham Court Road, steam engines and boilers.
T. Leach, London, steam wheel.
Jacob Perkins, London, certain improvements
Bainbridge and Thayer, rotatory engine.
1823. James Neville, Shad Thames, boiler and furnace.
William Johnson, Great Totham, furnace and boiler for saving fuel.
Robert Copland, Clerkenwell, " new combinations for gaining power."
N. Partridge, Stroud, mode of fixing boilders.
H. H. Price, Neath Abbey, Glamorganshire, improved machinery for steam boats.
William Jessop, Derby, metallic packing to piston.
Jacob Perkins, London, boiler.
Thomas Peel, Manchester, rotatory engine.
Jacob Perkins, London, certain improvements on steam engines.
Fisher and Horton, West Bromwich, boiler.
W. Jukes, Great Russel Street, regulating supply of water to boilers.
Bower and Bland, Leeds, steam engine without air-pump.
William Wigston, Derby, various improvements.
Robert Higgin, Norwich, method of consuming smoke.
James Larrey, Battersea, saving of fuel.
James Christie, London, combination of fuel for furnaces.
Jacob Perkins, London, furnaces and boilers.
[Samuel Brown, London, engine for effecting a vacuum without the use of steam.]
W. Furnival, Droitwich, for a boiler.
1824. Rev. Moses Isaacs, steam engine, machinery, &c.
Christie and Harper, peculiar combination of fuel for furnaces.
Maurice de Jough, Warrington, economising heat by combining a coke oven with a steam engine boiler.
Samuel Hall, Basford, improved steam engine.
George Vaughan, Sheffield, improved steam engine.
J. T. Paul, Westminster, mode of generating steam.

W. H James. Birmingham, locomotive carriages.
John M'Curdy, London, generating steam.
Philip Taylor, City Road, certain improvements.
W. Foreman, Bath, rotatory engines.
Pierre Alegre, Commercial Road, apparatus for generating steam.
Maudsley and Field, boilers for steam vessels.
John Moore, Bristol, improvements upon engine and apparatus.
David Gordon, London, locomotive steam carriage.
1825. Dr. Tilloch, Islington, various improvements.
Burstall and Hill, Surrey, locomotive steam carriage.
[William Grisenthwaite, King's Place, Nottinghamshire, improved air engine as a substitute for steam.]
Gillman and Sowerby, London, generating steam.
T. Sunderland, Blackheath, new combination of fuel for furnaces.
J. C. C. Raddatz, [*invented by Dr. Alban*], improvements in steam engine.
W. H. James, Birmingham, improved steam engine boiler.
Thompson and Barr, London, certain improvements in producing steam.
[M. J. Brunel, London, machinery for obtaining power by the expansion of the liquefiable gases, as a substitute for the steam engine.]
Jean Antoine Tessier, London, various improvements.
[Thomas Howard, London, for an engine in which the vapours of alcohol and ether are employed in lieu of steam.]
Josiah Easten, Bradford, locomotive steam carriage.
Goldsworthy Gurney, Argyle Street, apparatus for generating steam.
L. W. Wright, Lambeth, rotatory engine.
F. Halliday, Ham, rotatory engine.
Joseph Eve, Liverpool, rotatory engine, boiler, valves, &c.
J. M'Curdy, Strand, apparatus for generating steam.
1826. A. R. Lorent, London, application of steam.
James Neville, Shad Thames, apparatus for generating steam.
[Samuel Brown, Brompton, vacuum engine, addition to his former patent.]
A. Buffum and J. M'Curdy, London, improvements in steam engines.
Henry Higginson, St. Luke's, Middlesex, propelling boats by steam.
Joseph L. Marie, Marquis de Combis, of Leicester Square, rotatory engine, and apparatus connected therewith.
Robert Mickleham, London, certain improvements.
William Robinson, Strand, propelling vessels by steam.
[Count Adolphe Eugene de Posen, of Westminster, new engine for communicating power.
J. B. Wilks, of Tandridge Hall, Surrey, producing steam.
Barstall and Hill, of Leith, steam carriage.
John Costigan, Collen, Louth, various improvements.
Elijah Galloway, London, rotary engine.
1827. James Frazer, Houndsditch, improved boiler.
James Neville, Shad Thames, steam carriage.
Robert Copeland, Wilmington Square, "machinery for gaining power," being additions to former patent.
Robert Barlow, Chelsea, substitute for the crank.
[R. and J. Stirling, Glasgow, improved air engines.]
John White, Southampton, improved pistons and valves.
[Sir W. Congreve, Strand, new motive power.]
R. W. Fox and Joel Lean, Falmouth, various improvements.
Jacob Perkins, London, certain improvements.

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